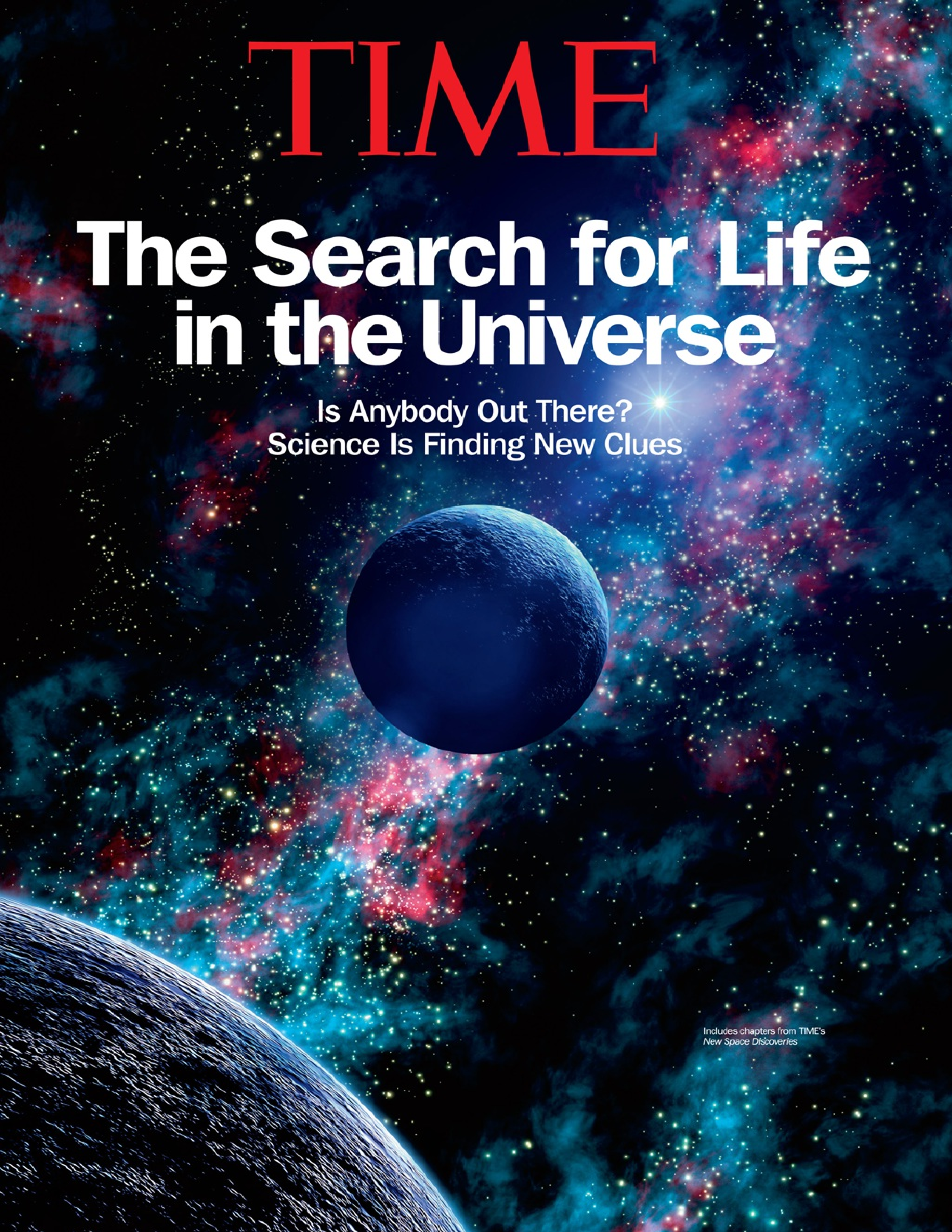
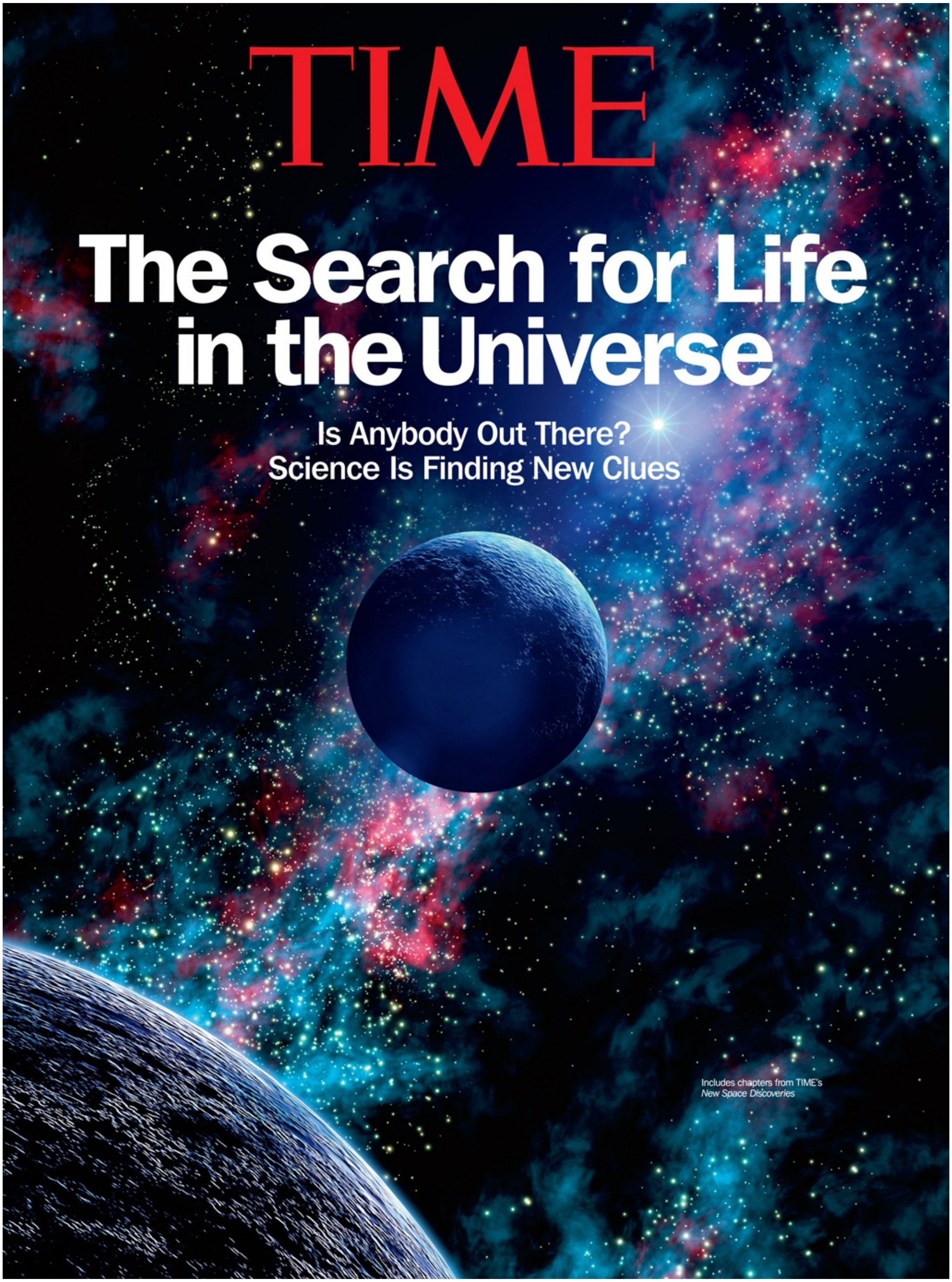
TIME

The Search for Life in the Universe

Is Anybody Out There? Science Is Finding New Clues



Includes chapters from TIME's
New Space Discoveries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TIME

THE SEARCH FOR LIFE IN THE UNIVERSE

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Parts of this book were previously published in TIME's New Space Discoveries *and in* TIME *magazine* .

THE GREAT CANARY TELESCOPE, which began scientific observations in 2009 in the Canary Islands, is the world's largest single-mirror optical telescope.

Waiting for a sign

BY MICHAEL D. LEMONICK

WHEN THE SUBJECT OF extraterrestrials comes up in polite conversation, any scientist whose lonely life's work is listening for distant radio signals often has to deal with what Seth Shostak of the SETI Institute calls the "giggle factor." And to be fair, amid a backdrop of *The X-Files* and *The Twilight Zone* and conspiracy nuts convinced the Air Force has aliens on ice in Area 51—not to mention those who figure visitors from space must have built the pyramids—even learned men can begin to sound ridiculous. Besides, no one has heard or seen anything so far, have they?

Yet whether life exists on planets other than ours is a scientific and philosophical issue of real import, its pedigree far older than many realize. As early as the sixth century B.C., the Pythagoreans—mathematically inclined philosophers (in other words, serious Greeks)—thought the moon hosted lush plant and animal life. In the 15th century A.D., German astronomer Nicholas of Cusa suggested that many "stars and parts of the heavens" are inhabited. In 1600 the Italian Giordano Bruno was burned at the stake for, among other things, saying, "The countless worlds in the universe are no worse and no less inhabited than our Earth." And astronomer William Herschel (1738– 1822), discoverer of Uranus and inventor of many modern astronomy techniques, believed that the moon, Mars and even the sun were home to sentient beings.

Sure, even smart people can be very wrong. Still, by the late 1800s, the notion that other planets in our solar system were home to life of one sort or another was more or less mainstream, egged on by Giovanni Schiaparelli, an Italian astronomer who uncovered what seemed to be visual confirmation. Peering through his telescope at Mars, he made out ruts that crisscrossed the planet. "Canali," he called them—channels—which he incautiously interpreted to be waterways dug by Martians to support their agriculture.

Soon after, Boston aristocrat Percival Lowell sank much of his wealth into building a private observatory in Arizona. He saw the canals too, and because of his man-of-letters reputation—not only did he go to Harvard, his brother was its president—his findings were trumpeted as fact.

They weren't, of course. The canals were an optical illusion, the result of too much squinting through a too-weak telescope. And in the aftermath of Lowell's public humiliation, all talk of alien life was avoided by the scientific community for decades, consigned to fiction writers such as H.G. Wells and Edgar Rice Burroughs.

The rationally curious couldn't stay gun-shy forever, though. For many, the idea that life is unique to a single location in a universe billions of light-years wide seemed just too far-fetched. And in 1959, in a paper published in *Nature*, the Cornell University physicists Philip Morrison and Giuseppe Cocconi argued that "near some star rather like the sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us." It would be foolish not to search for the inevitable signals of these civilizations. "The probability of success is difficult to estimate," they wrote, "but if we never search, the chance of success is zero."

Search parties were quick to convene. From the start, scientists were resigned to the fact that advanced alien civilizations, if they existed, would be the rarest form of life in the cosmos. Evolution, the thinking went, doesn't necessarily progress in a particular direction. Single-celled organisms are almost certainly the first step, but what happens after could vary wildly, depending on local conditions. On Earth, it took some 2 billion years for single cells to evolve into multicellular organisms. On another world, it might take much longer, or it might not happen at all. On Earth, mammals began to flourish only after the dinosaurs were wiped out by an asteroid. But had that asteroid scooted by our planet instead of smashing into it, giant lizards might still be dominating the land.

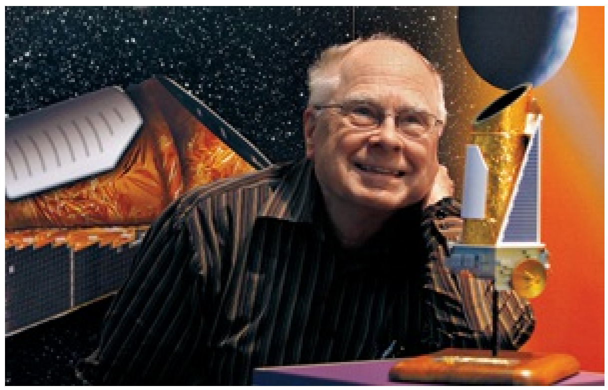
So astrobiologists are thinking small, figuring the first extraterrestrial life they find will be simple, bacteria-like organisms, just because they're likely to be the most common specimens. Maybe they'll be in the soil of Mars or the subsurface oceans of the moons Europa (Jupiter), Enceladus (Saturn) or Ganymede (Jupiter). Maybe we'll know them only by their waste gases circulating in the atmosphere of a distant exoplanet.

Then again, maybe an ET radio signal or laser beam is even now racing toward us at light speed. So don't be surprised if the millennia-old question of whether we're alone is resolved in the next decade or two by a new army of telescopes, probes and rovers. Unless, of course, it is answered with an electromagnetic ping the day after tomorrow.

Triumph of the Planet Hunters

Recent discoveries suggest that our galaxy contains billions of Earth-size worlds. Now astronomers are narrowing the search—for planets that most closely resemble ours in the particular ways that support life

BY MICHAEL D. LEMONICK

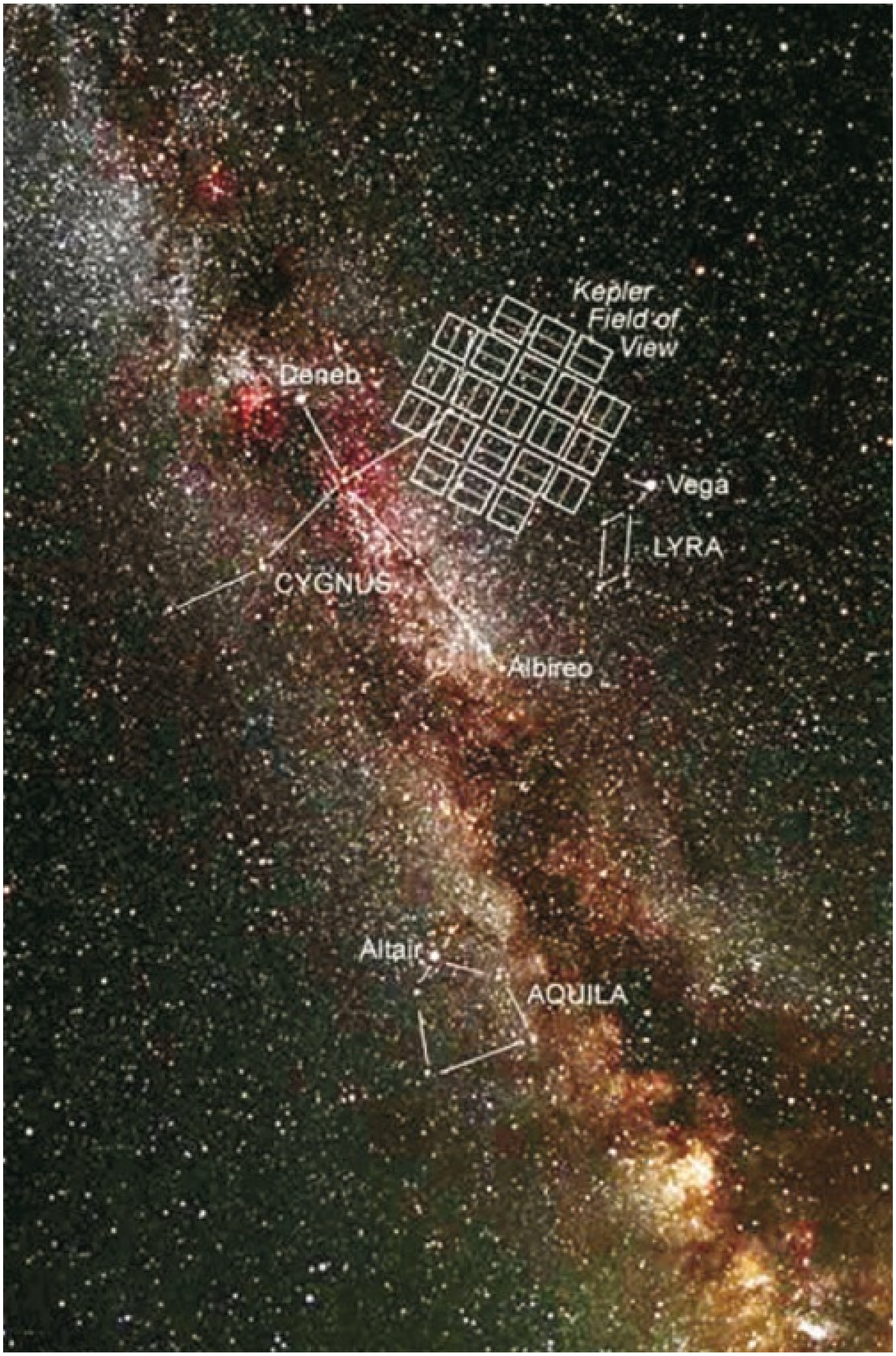


BESIDE A MODEL of the Kepler spacecraft at NASA's Ames Research Center, William Borucki, the mission's chief scientist, lectures on the space observatory, which orbits the sun in search of distant Earth-like planets.

LOOK UP ON A CLEAR, MOONLESS night, far from city lights, and you can see thousands of stars twinkling in the dark vault of the sky. Astronomers, of course, will assure you that the stars aren't really twinkling. Rather, it's an illusion caused by the shimmering of Earth's atmosphere, something like the rippling air you see coming off the hood of a car on a hot summer day.

In fact, many stars are twinkling, if only in a way that a clear-eyed telescope orbiting high above the atmosphere can make out. More precisely, the stars are winking at us, dimming just a bit on a schedule as precise as clockwork. Others are wobbling in place, moving toward us and away, then back again with the same sort of rhythm.

The explanation for all this winking and wobbling is that most stars aren't drifting through the Milky Way in solitude. They're accompanied by planets, just as the sun is; those winks and wobbles are proof of that. When a planet passes precisely in front of its star from Earth's point of view, the star dims subtly. Even when things aren't lined up quite so perfectly, the planet's gravity tugs the star to and fro as it orbits, causing measurable changes in starlight.



KEPLER TAKES AIM at the Milky Way. Each rectangle indicates a specific target region covered by one of the 42 paired photographic CCD elements.

By noting the winks and wobbles with exacting precision, astronomers have found thousands of alien worlds, called exoplanets, in an almost bewildering

variety of sizes and orbits, since the first was discovered just two decades ago. As yet, none truly resemble our Earth—a world of similar size, orbiting at just the right distance from its star, so its temperature is neither too hot nor too cold to harbor life.

Astronomers are on the verge of finding one, though, and given how short a time they have been in the planet-hunting business, when they do, it will be an extraordinary achievement. "They discovered the first planet orbiting a sunlike star in 1995, when I was in college," says Eric Ford, an astronomer at Penn State, "and now I get to help search for the first Earth-like planets. That's pretty cool."

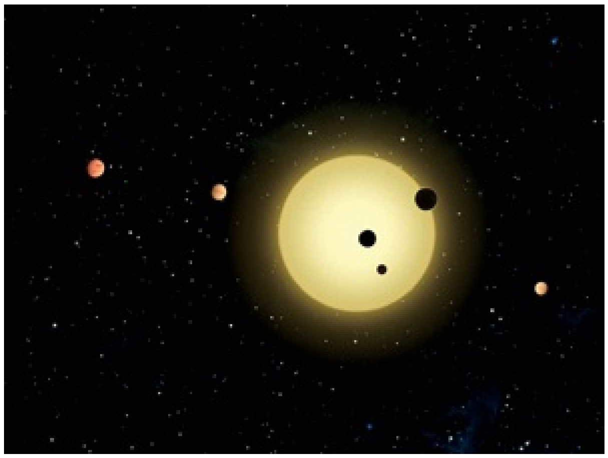
It could also be transformative. Since ancient Greece at least, philosophers have argued the question of whether we are alone in the cosmos. While finding a second Earth won't end that debate right away, it will take astrobiologists working at the intersection of astronomy and biology a big step closer by giving them somewhere to look.

FOR YEARS, THE ODDS-ON FAVORITE to make such a discovery was the Kepler mission, a telescope whose sole function since its 2009 launch was to stare ceaselessly at a field of some 156,000 stars located in the northern sky between the constellations Cygnus and Lyra, waiting for any to wink as a planet passes by. The project was developed by Bill Borucki at the NASA Ames Research Center in California (and was rejected four times before NASA finally gave it the go-ahead). Borucki reasoned that if you focus on just one star hoping a planet will pass it, you'll almost certainly fail, as planet and star have to line up just right for the event to be visible. Look at many tens of thousands, however, and you're a lot more likely to catch a planet in the act.

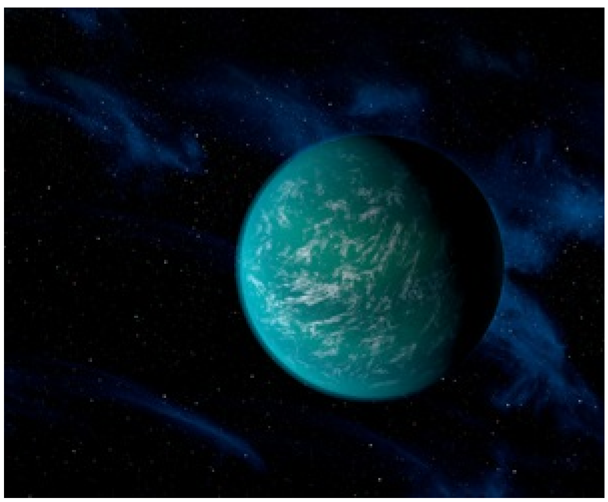
Kepler has succeeded, spectacularly. At last count it had discovered more than 4,000 "planet candidates," and follow-up observations have confirmed nearly a quarter of them as bona fide planets. Still, true twins of Earth remain elusive. While Kepler identified more than 100 Earth-size planets, virtually all of them are too hot for life as we know it. Then again, extrapolating from what Kepler has seen in that small patch of sky, there could be as many as 40 billion Earths in the Milky Way alone—with the nearest no more than 12 light-years away. Of the current search field, Harvard's Courtney Dressing, who made the calculation, says, "Statistically speaking, this is like a stroll across the park."

Kepler also revealed the existence of a class of worlds that doesn't exist in our own solar system: super-Earths, which lie in size midway between Earth and Neptune.

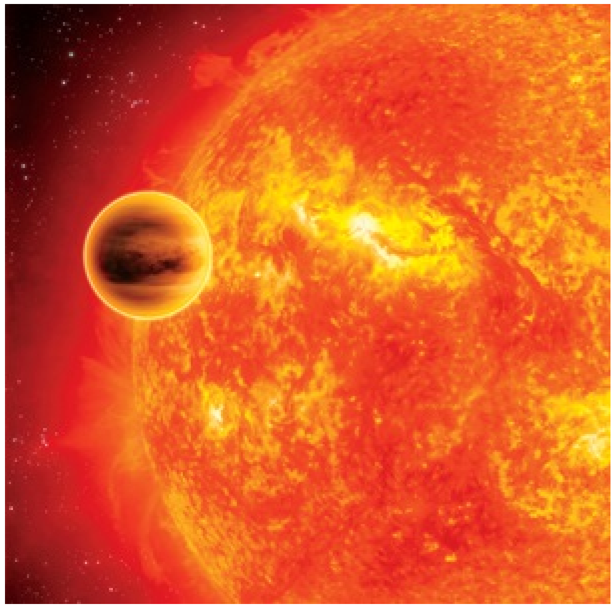
It's not yet clear whether these tend to more closely resemble Earth—mostly rock, with a relatively thin atmosphere—or Neptune, whose rocky core is surrounded by a deep shroud of gas. In all likelihood, says Andrew Howard of the University of Hawaii, the answer is both: "There are a lot of ways to make a planet twice the size of Earth," Howard says. "For me, it's kind of amazing that we keep expecting planetary systems like our own, and they keep turning out to be different."



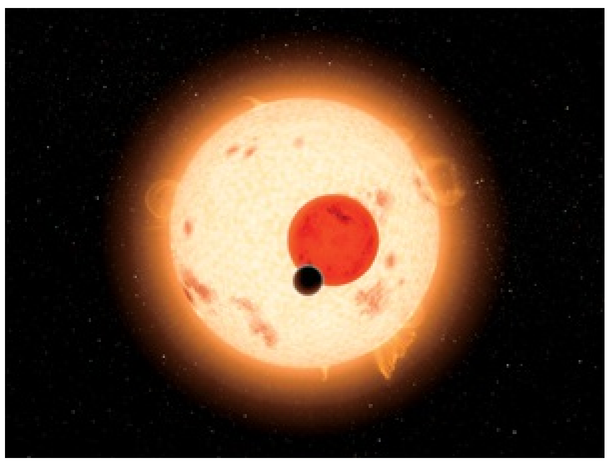
Kepler 11's six planets orbiting their sun



Kepler 22b, the first planet found to orbit the "habitable zone," where water can exist



Gas giant H189733b passing its star



Planet Kepler 16b circling its two stars

In fact, the galaxy is well furnished with all sorts of oddball systems. Early hints of this emerged with the discovery of the first extrasolar planet back in the mid-1990s. Found by Swiss astronomers Michel Mayor and Didier Queloz, who noticed the parent star wobbling in place, the world known as 51 Pegasi b was "just weird," says Harvard planet hunter David Charbonneau. It was about half as massive as Jupiter but much closer to its star than Mercury is to the sun. Its year was just four days long, which theorists had considered impossible for a giant planet.

Yet as new planets trickled in over the next few years, it became clear that "hot Jupiters" weren't uncommon at all. And when the Kepler came online, the strangeness just got stranger. In 2011, for example, the probe found a planetary system around a star, Kepler 11, that contains no fewer than six planets, all

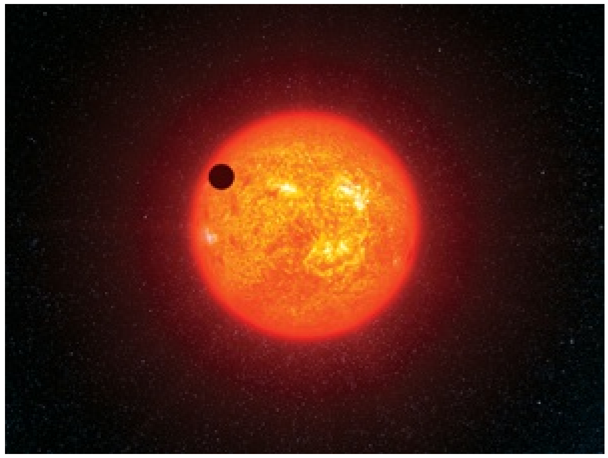
significantly bigger than Earth, and five of which were crammed inside an orbit equivalent to Mercury's. "It's remarkable," astronomer Ford, a co-author of the discovery paper, told TIME . "We never expected to see something like this."

Likewise, astronomers couldn't have imagined Kepler 16b, a Saturn-size planet found late in 2011 that circles not one star but a pair whirling around each other in a tightly bound orbit. Theorists had doubted such worlds could exist in such a gravitationally unsettled environment, but once again the universe didn't seem to care. "When we first saw it," said co-discoverer Joshua Carter of the Harvard-Smithsonian Center for Astrophysics, "I thought, Wow, this is just amazing. It's hard not to get excited. This is too much fun."

Unfortunately, Kepler ran into a problem. In 2013, a reaction wheel, which steadies the telescope so its gaze stays solidly locked on target stars, failed. Now with only two functioning reaction wheels, Kepler no longer has the precision to discern those revealing winks. Still, terabytes of unprocessed data from the first four years of the mission continue to produce discoveries.

Maybe the most exciting: Kepler 186f, announced nearly a year after the reaction-wheel failure. It is Earth-size, almost certainly rocky, and orbits in the habitable zone of its star. At 500 light-years away, however, it's too distant for follow-up observation—for example, to determine if it holds significant amounts of life-sustaining water. In any case, Kepler 186f isn't likely to be the final surprise the mission uncovers. "The candidates it's finding," says David Latham of the Harvard-Smithsonian Center, "will keep us busy for years."

Harvard's David Charbonneau heads up the MEarth project, which led to the discovery of GJ 1214b.



EXOPLANET GJ 1214B, DEPICTED orbiting its small, reddish M-dwarf star, which is about 40 light-years from Earth. It is the first exoplanet whose atmosphere was analyzed.

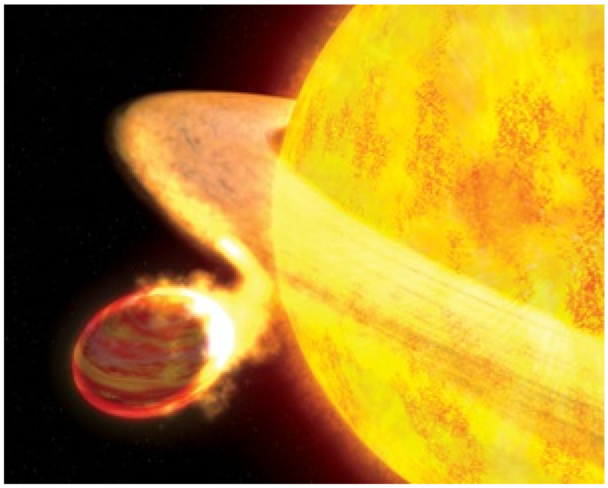
The embarrassment of riches from Kepler is being matched by those arising from other telescopes, both in space and on the ground. The SuperWASP (for Wide Angle Search for Planets) survey, with scopes in South Africa and the Canary Islands, has found 26 planets of its own. Among them is WASP-12b, a world strangely rich in carbon and so big that it's probably mostly gas, though there could be smaller, solid planets nearby. Raising the potential dazzle factor, co-discoverer Nikku Madhusudhan, now at Yale, told TIME, "On a carbon-rich world, you could have big landforms made of pure diamond."

Then there's the MEarth project, led by Charbonneau, which focuses not on sunlike stars but on the much smaller, dimmer, redder and more numerous M-dwarfs that make up 70% or more of the Milky Way. "I was taught in school that we orbit an average star," says Charbonneau, "but it's a lie. If the sun is a 100-watt bulb, most stars are like little Christmas lights." That's an advantage for planet hunters, though. A planet that passes in front of an M-dwarf blots out a bigger percentage of the tiny star's light. Plus, the star can be made to wobble more easily.

MEarth's biggest payoff to date is GJ 1214b, a super-Earth revealed in 2009, just a month before Kepler found its own first planet. Like the carbon planet found by SuperWASP, this one has an unusual makeup: less than a third the size of Earth, it seems to be half rock, half water. "It's a top-of-the-top discovery in the quest for Earth-size planets," said University of California, Berkeley's Geoff Marcy, the world's leading (human) planet hunter, when GJ 1214b was announced.

But even superlative discoveries are destined to be overtaken in the fast-moving world of exoplanetology. In March 2012, a European team operating a telescope in the high desert of Chile said it had found no fewer than nine super-Earths in a scan

of 108 nearby M-dwarf stars, including two in stars' habitable zones. At that rate, there should be more than 3 billion such planets in the Milky Way—a number that would have been mind-blowing a few years ago. Yet, says Harvard planet hunter John Johnson, that calculation "was greeted almost with yawns, because it's gotten to the point where we're bored with super-Earths."



THE HOTTEST KNOWN PLANET in the Milky Way is WASP-12b, discovered by SuperWASP (for Wide Angle Search for Planets). The carbon-rich exoplanet is so close to its yellow dwarf star that it superheats to 2,800°F and bulges due to tidal forces.

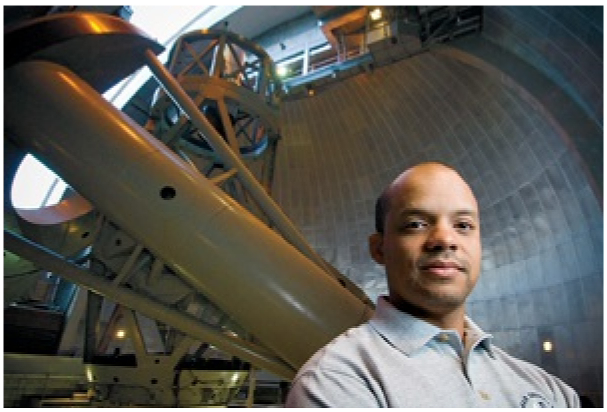
That is almost surely an exaggeration. While astronomers are ultimately looking for a mirror Earth similar in size and composition to our own (carbon planets and giant blobs of water need not apply), it's not clear that larger planets couldn't be life-sustaining as well. Says Dimitar Sasselov, director of the Harvard Origins of Life Initiative, "I don't see a dividing line [for planets friendly to life] anywhere between one Earth mass and five Earth masses and even 10 Earth masses."

Johnson isn't even slightly bored with planets in this size range: He's building a "micro-observatory" atop Mount Palomar, in California, in which four modest-size telescopes will work in concert to find nearby habitable super-Earths. "We're just going to hammer away at the nearest, brightest stars," he says, "and basically shake the tree and see what falls out." A follow-on space mission to Kepler, known as the Transiting Exoplanet Survey Satellite, is set to do something similar, with far greater precision.

BUT IF SUPER-EARTHS MAY harbor life, the only place we know life exists for sure is on Earth itself, so a true twin of our sustaining home base remains the smartest kind of planet to seek. Scientists are working now to isolate a promising handful of relatively nearby candidates, after which they know they will have to

observe them more intensely: Winks and wobbles can prove a planet exists, but life has different telltale signs, such as ozone molecules in the atmosphere.

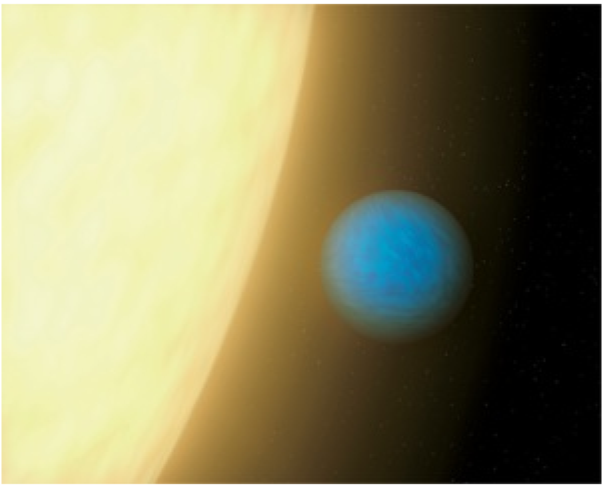
Problem is, those indicators can be an elusive quarry for our existing telescopes. When exoplanets first started to show up in the 1990s, NASA was on its way to a solution, announcing a mission called the Terrestrial Planet Finder (TPF), four huge space telescopes flying in tight formation out in the neighborhood of Jupiter. To astronomers' frustration, though, that project was soon back-burnered, replaced with a far less ambitious design—a single telescope armed with technology that blots out the light of a star so planets orbiting around it can show through. Unfortunately, even this slimmed-down version has proved too expensive for a cash-strapped NASA to fund at the moment.



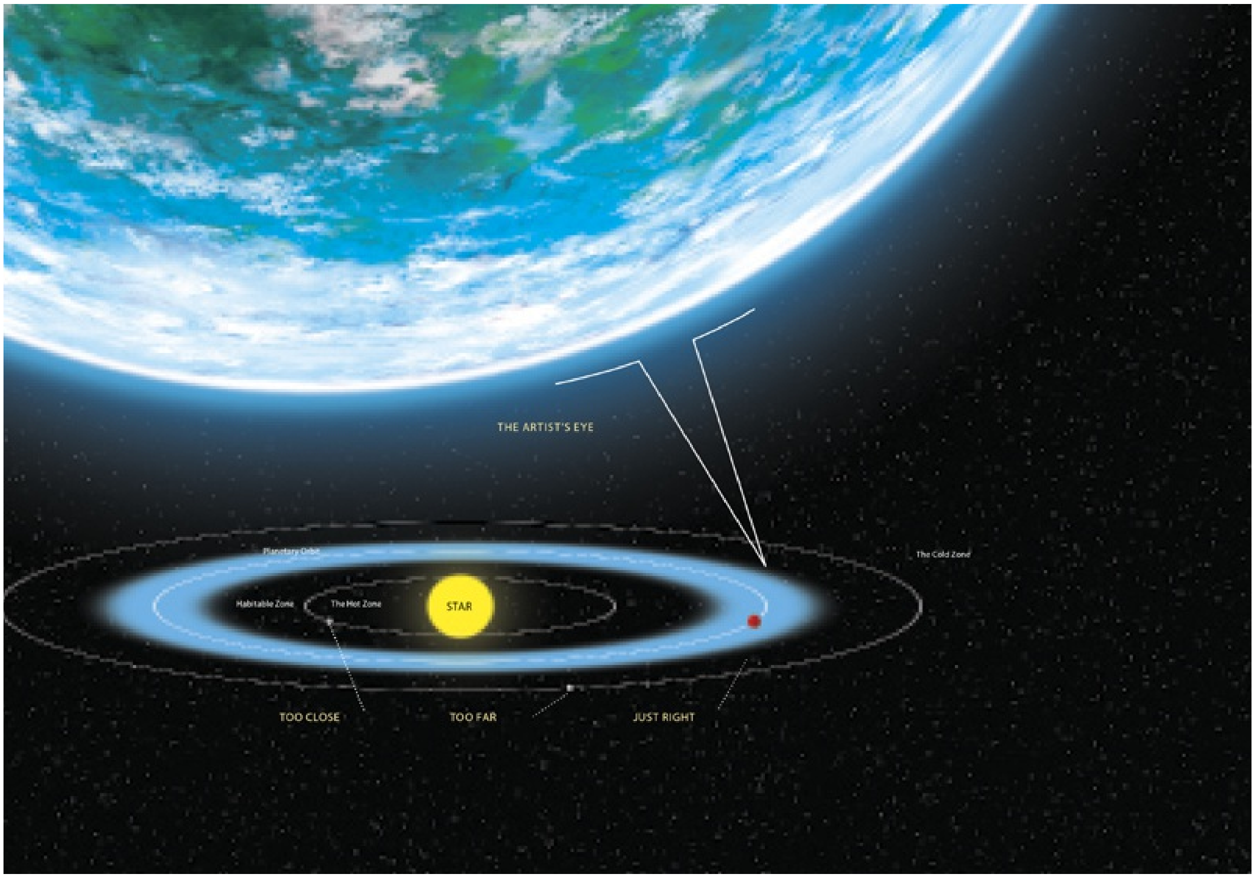
Astronomer John Johnson

So for now, hope rests with the James Webb Space Telescope. Slated to launch by 2018, it may be able to shoulder some of the important planet-imaging duties until a version of TPF is authorized. Given the astonishing progress planet hunters have made over the past few years in finding worlds closer and closer to the size and temperature of our own, there will almost certainly be plenty of candidates for it to look at.

Will any of them betray the presence of life? That, of course, remains an open question. But there is great satisfaction in knowing we are on track to answer it, one way or another, before much more time goes by. "Over the past 15 years," says Johnson, "this idea has moved from the realm of science fiction to credible discussion. There are a lot of people left over from the old days who will still scoff at the notion. But we now know that the galaxy is teeming with Earth-size planets. I mean, we know this."



PLANET 55 CANCRI E orbits its sun so closely that it heats to more than 3,000°F. Life-sustaining planets would be thousands of degrees cooler and difficult to detect, but astronomer John Johnson believes they could exist.



Goldilocks Worlds: where things are just right for life

THE ARTIST'S EYE

No, this Earth-like world does not exist, but similar ones are surely out there.

TOO CLOSE

The heat from a star can boil off water from planets that venture too close to it and warm their surfaces to deadly temperatures. Dry, airless Mercury and hothouse Venus illustrate the perils of proximity.

TOO FAR
Space is a cold place, and you don't have to edge far from your home star before water freezes solid. Atmosphere retains heat, and Mars might have been a thriving world if it had held on to more of its air.

JUST RIGHT
Earth exists in the habitable zone, where liquid water can be present in abundance. Life as we know it can't exist without water. Life as we haven't imagined it is, admittedly, more of a riddle.

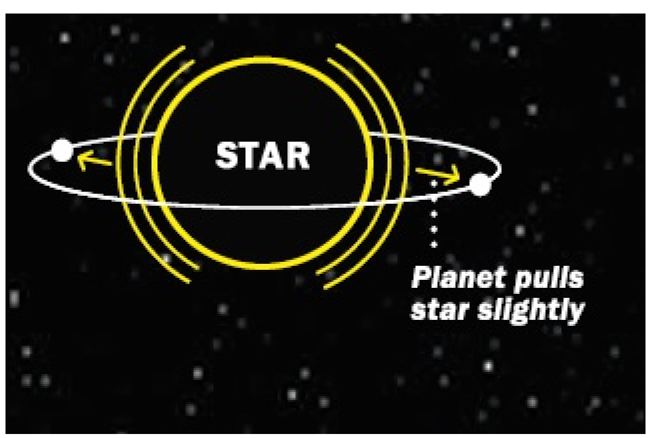
Three Ways to Spot Planets

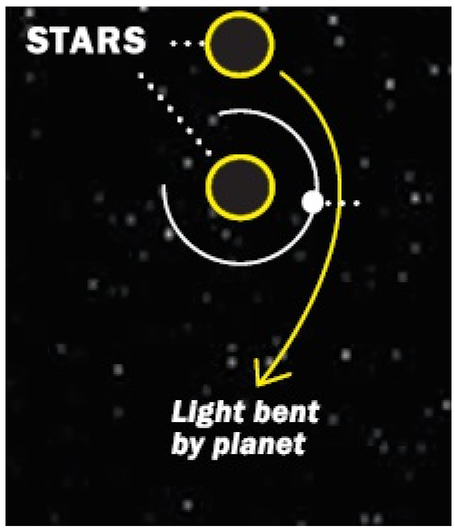
1. WOBBLE
As a planet orbits, it gravitationally tugs its parent star this way and that. By measuring this motion, scientists can verify a planet's existence and infer its mass.

2. TRANSIT
Light from even the brightest star is slightly dimmed as an orbiting planet passes in front of it. The degree of dimming indicates the size of the planet.

3. GRAVITATIONAL MICROLENSING
Gravity bends light. Hence, a planet may distort the image of its star. This reveals the existence of a planet but little more.

Planets galore, everywhere astronomers look

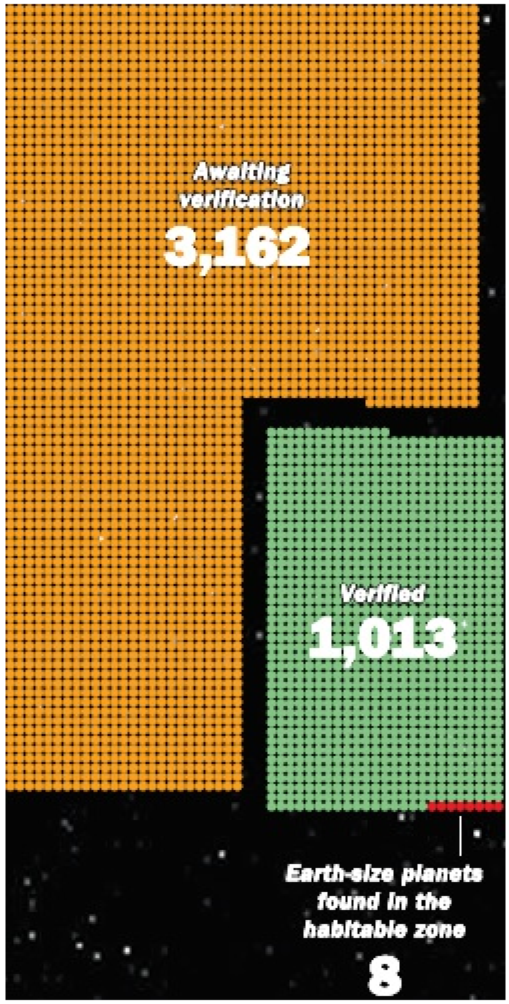




New Kids on the Block

NASA'S Kepler Hall of Fame: Of the more than 1,000 verified plants found by the kepler Space Telescope, eight are less than twice Earth-size and in their star's habitable zone. All eight orbit stars that are cooler and smaller than our sun.

4,175 Candidate plants found by the Kepler Space Telescope as of January 2015. Here's the breakdown:

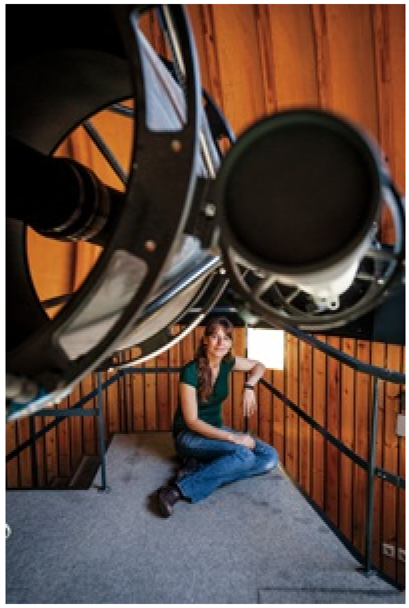


Exoplanet candidates are findings that have yet to be confirmed as actual exoplanet discoveries. Candidate planets are 80% to 90% likely to be verfied.

Finding a Second Earth

Lisa Kaltenegger uses data about our planet's geology and meteorology to identify possible siblings

BY JEFFREY KLUGER


LISA KALTENEGGER at the Max Planck Institute for Astronomy in Germany, one of several sites she uses in her quest for just-right exoplanets

In a galaxy with 300 billion stars, there are surely untold billions of planets out there. Is anyone home on any of them?

Few astronomers are approaching this question as creatively as Lisa Kaltenegger, a 36-year-old exoplanet investigator who is a lecturer at Harvard University, a professor at Cornell University, and leader of a research group at the Max Planck Institute for Astronomy in Heidelberg, Germany. The focus of her work is not actually discovering exoplanets, planets orbiting distant stars; that is mostly the job of the Kepler space telescope. Rather, she and her team are modeling them—hoovering up massive amounts of data from Kepler, the Hubble Space Telescope and various ground telescopes and processing it through computer models to determine which worlds could harbor life. These days, so-called Big Data is inescapable, from algorithms that predict what you'll buy to government surveillance that watches what you do. So it only makes sense that it could also be the key to finding extraterrestrial life.

Kaltenegger's model is a complex one, factoring in a planet's size, mass, composition and orbit—specifically, whether it is in the habitable zone around its star, where temperatures would remain hospitable and water would remain liquid. Just as important are the size, nature and temperature of the star itself, since those like our sun have a very different profile from, for example, a red giant's or a white dwarf's. Kaltenegger's calculations even include a dash of the fantastical. "What if you have more than one host star? What if you see Tatooine?" she asks, referring to

the childhood home of Star Wars hero Luke Skywalker.

All that is impressive but not groundbreaking. Where Kaltenegger shakes things up is in her use of data from the only planet in the universe that, by definition, cannot wear the exo prefix: Earth. Her models are based on data about Earth's meteorology, geology and volcanology, plus one other important feature: its history.

Our planet, seen by extraterrestrials, would look very different depending on the moment when it is observed. Take a look at us 3.9 billion years ago, and we would have had a barren, globe-girdling ocean and an atmosphere made mostly of hydrogen sulfide, carbon dioxide and nitrogen. Not exactly the rain forest. Check back 2.4 billion years ago, and Earth's atmosphere was mostly nitrogen, carbon dioxide and methane; blue-green algae were blooming in the seas. Not long after that, photosynthesis began flooding the atmosphere with oxygen, leading to an explosion of our modern forms of life.

Every bit of this could have been observed by faraway civilizations studying Earth with a technique known as spectral analysis. Since light coming from a planet breaks down into different wavelengths depending on the planet's chemical composition, all you need to know is which elements are represented by which spectra, and you can pretty much figure out what's going on in the atmosphere. In similar fashion, we are able to make observations about other worlds. "We've determined how this spectral fingerprint looks for a young and an older Earth," Kaltenegger says. "We use that as an alien ID chart for other planets."

On this score, Kaltenegger is well ahead of the curve. Telescopes can't yet resolve exoplanets visually. In 2017, though, NASA will launch the Transiting Exoplanet Survey Satellite specifically to look for exoplanet atmospherics. Kaltenegger, as a pioneer in the field, will be one of the mission scientists. Once instruments like that and others come online, it should be even easier to find potentially life-bearing planets than astronomers thought possible.

A study released early this year by Kaltenegger, who will be one of the scientists on the mission, strongly supports this conclusion. She and Cornell research associate Ramses Ramirez considered not just planetary systems with mature stars but also those with stars in what is known as the pre-main sequence phase, when they are larger and brighter and have not yet contracted enough to ignite nuclear fusion.

During this period, which can last 2.5 billion years, life has plenty of time to emerge. Once the star contracts, the planet becomes more visible to telescopes, no

longer lost in the glare of solar fires. And though the radiated warmth of the star inevitably decreases with its luminosity, any organisms that have already taken hold on the planet could adapt by moving belowground or underwater.

"Our study adds new targets to the search for habitable worlds," Kaltenegger told *Astrobiology* magazine, a NASA-sponsored journal, shortly before her research was published. "On Earth, life emerged within the first billion years." The odds, she believes, increasingly favor the possibility that it has emerged in other places—maybe many other places—as well.

"With billions of rocky worlds," she says, "life would have to be extremely picky not to be able to evolve out there, wouldn't you say?"

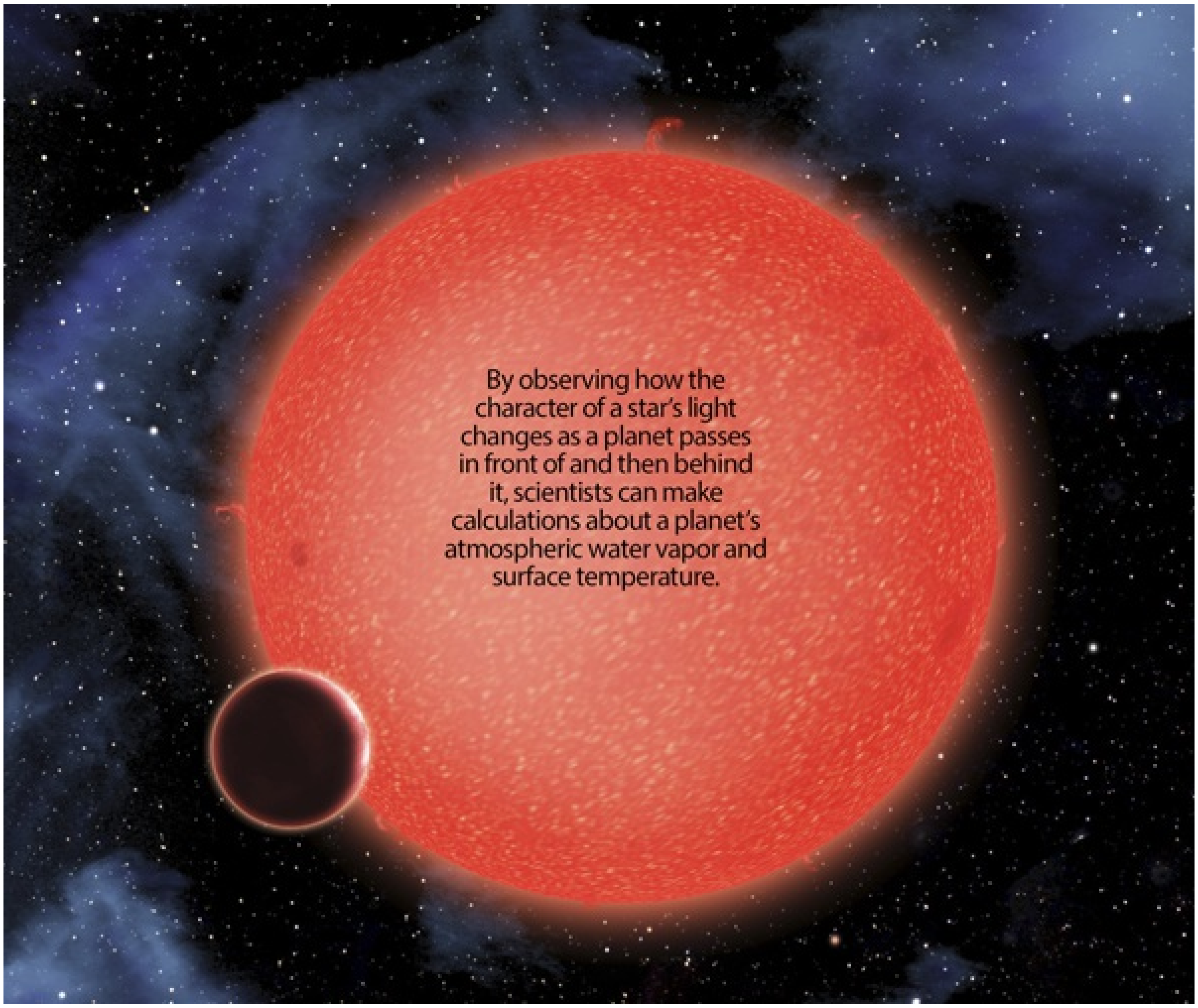
There's Something in the Air Up There

The same cosmic trick of the light that has allowed us to discover planets much too remote for our telescopes to see is also helping us determine which of their alien atmospheres could possibly support life

BY MICHAEL D. LEMONICK

SCORCHED PLANET HD 209458b is 150 light-years away in the constellation Pegasus. This rendering depicts its proximity to a sunlike star.

How scientists "see" exoplanets

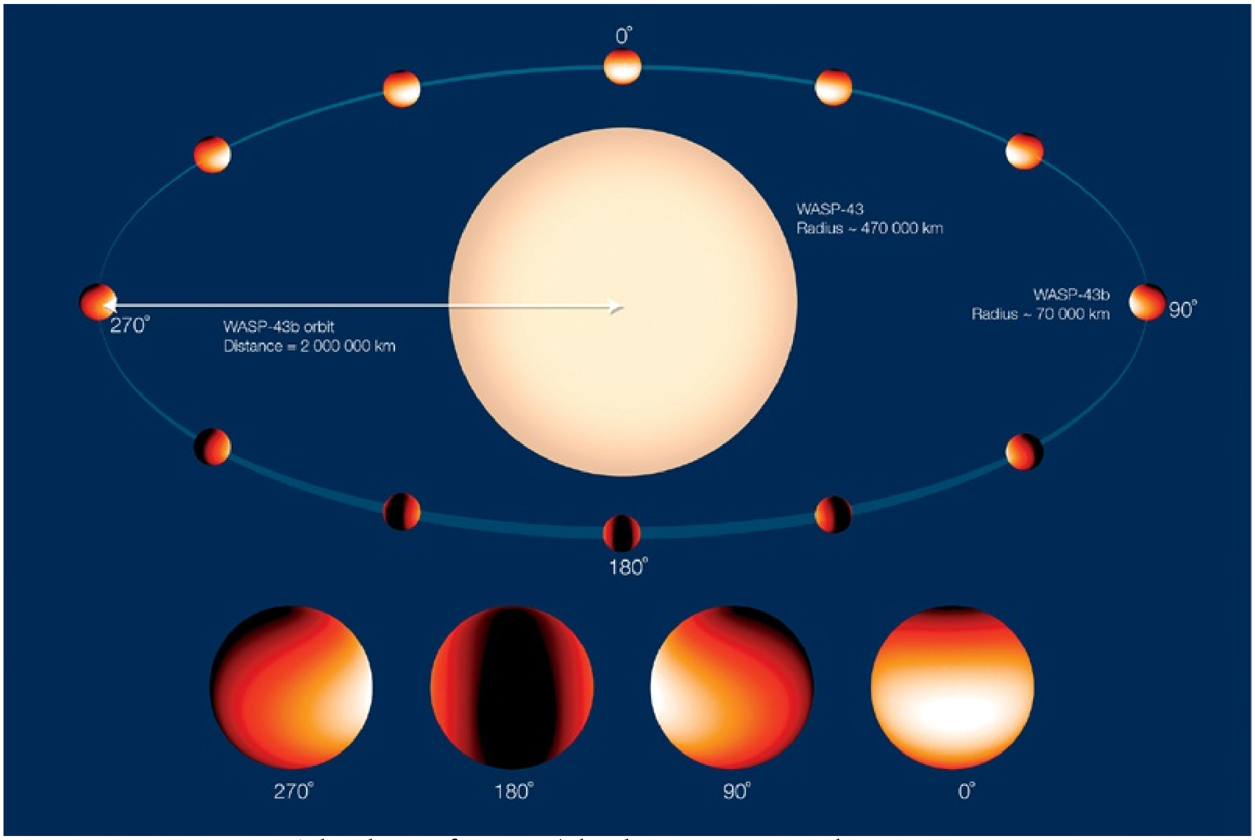


GJ 1214 b, orbiting its star, is a super-Earth.

WHEN A TRAILBLAZING handful of astronomers first detected exoplanets orbiting distant stars back in the 1990s, the effect on their field was nothing short of game-changing. Before their discoveries, the hottest area in astrophysics was cosmology, the study of the origin and evolution of the universe. Afterward, senior stargazers in droves dropped what they were doing to turn their attention to alien planets, and graduate students by the score rethought their career paths in a hurry. “When I would talk to nonscientists about my work in cosmology,” says Harvard's David Charbonneau, who was, in fact, one of those grad students, “they looked confused.” Once he switched interests, though, his explanations got far fewer blank stares. Everyone could understand the guy who held up two fists—one representing a star, the other its planet—then mimicked the one orbiting the other to demonstrate how worlds revealed their existence.

NASA boarded the bandwagon, too, developing its own long-range plan for

exoplanet research. Step 1: Find as many worlds as possible by indirect means (that is, the real-life version of Charbonneau's dual-fist demonstration, the lone means of detection at the time). Step 2: Build a Next Generation Space Telescope capable of collecting direct images of the biggest exoplanets. Step 3: Follow up with a gigantic Terrestrial Planet Finder telescope that could image smaller, more Earth-like planets.



The phases of WASP-43b, a hot Jupiter, as it orbits its star

In the end, harsh reality overtook the government agency's ambitious to-do list. Budget and technical woes shrunk the Next Generation project—now known as the James Webb Space Telescope, or JWST—and delayed it to 2018, and the Terrestrial Planet Finder was delayed indefinitely.

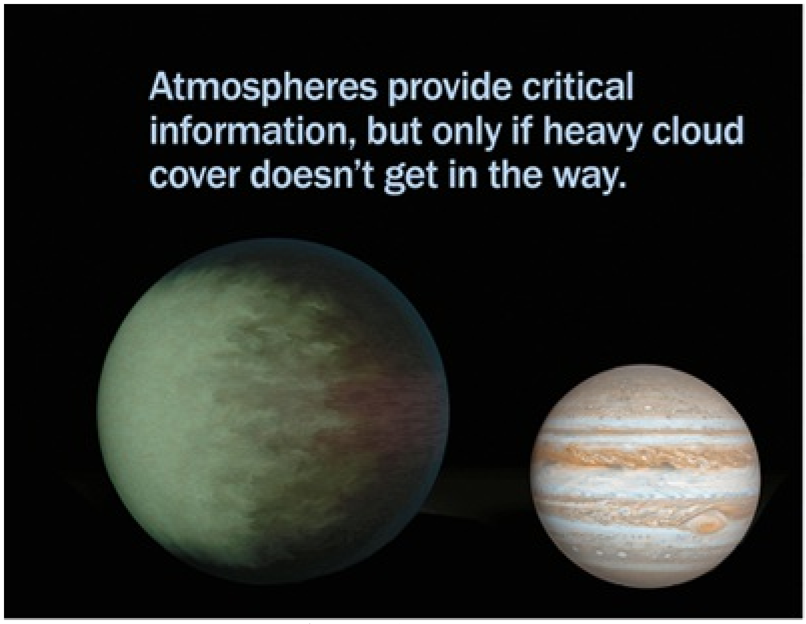
Elsewhere, however, scientists didn't receive the austerity memo. As far back as 2001, they were already beginning to figure out ways not only to detect exoplanets but to analyze their atmospheres, in the hope of finding chemicals—oxygen, say—that suggest the presence of life. The earliest subjects were giant Jupiter-size bodies, but more recently super-Earths, which fall between Earth and Neptune in size, have received similar treatment. And if signs of life remain elusive, evidence of water vapor, clouds and other life-teasing features speak to how far the field has

advanced in a short while—and hint at even more significant exploration to come. "We'll be able to use our techniques to get to the sensitivity required to really study Earth-size planets," says Laura Kreidberg of the University of Chicago.

NASA'S James Webb Space Telescope, successor to—and twice as large as—Hubble, launches in 2018. Among other things, it will be more sensitive to water vapor.

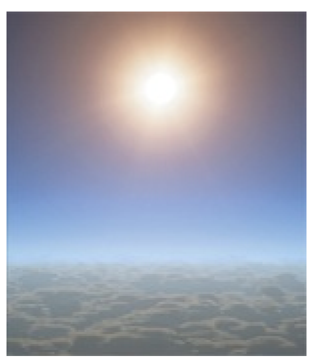
To be clear, no one is getting any direct looks at exoplanets just yet; in fact, that remains a far-off goal. Instead we get our glimpses by observing changes in light. One way to do that is to focus on the parent star. When a planet passes directly between its star and Earth, its silhouette slightly dims the amount of starlight. The light's character, from which we glean evidence of its chemistry, changes a bit too, as it passes through the planet's atmosphere on the way to our telescopes.

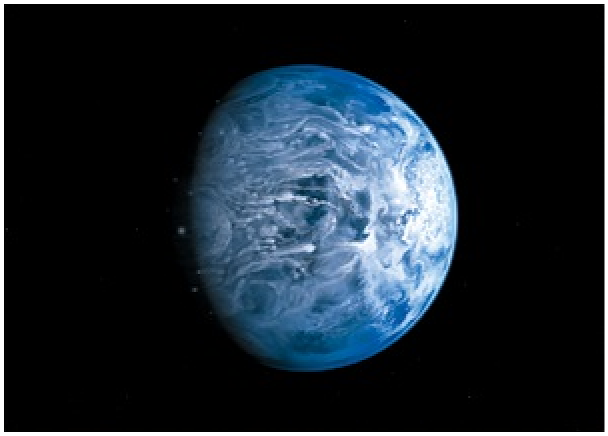
The other way to see what we otherwise can't is to consider the star and planet together. When a planet orbits behind a star, their combined light lessens as the planet's glow is obstructed and we pick up the star's alone. Similarly, the character of their light changes. The planet's blocked glow contains spectral hints of its atmospheric makeup. By noting what is missing from the overall chemical mix, observers can deduce what compounds belong solely to the planet.



Kepler-7b, 1.5 times the radius of Jupiter(bottom), was the first exoplanet to have its clouds mapped


An artist's conception of what clouds look like on other planets.


Another image of a planet with clear skies, resembling HAT-P-11b, which is the size of Neptune



An illustration of HD 189733b, a huge gas giant that has temperatures of more than 1,800° and fierce 4,300-mph winds. Scientists say it rains molten glass there

Kreidberg and her colleagues use both methods. In one instance they were able to calculate the amount of water vapor in the atmosphere of a world known as WASP-43b—a so-called hot Jupiter because although it is also a giant gas ball like our solar system's biggest planet (albeit about twice as massive), its orbit is far tighter than Mercury's, making it too hot for life. Still, that water vapor measurement is an important advance. Water, of course, is an essential nourisher of biology—at least, of the biology we know—and being able to determine its exact amount should someday tip off scientists to worlds where life might thrive.

Another University of Chicago astronomer, Jacob Bean, used the Hubble telescope to chart a precise temperature map of WASP-43b's surface. He watched the planet through three consecutive 20-hour orbits, and as it went through its phases—a thin crescent as it neared the front, showing a dark backside to Earth; swelling to nearly full as it prepared to duck behind—Bean determined how much heat emanated from it during each one. Recording different wavelengths of light, he also saw that temperature varied with altitude and, coincidentally, water concentration did too. Considering we are nowhere close to seeing exoplanets, we sure can learn a lot about them. "This was an unprecedented use of the Hubble," says Bean, "and really points the way to what we will do with JWST."

Actually, all the research on WASP-43b is a dry run for the kinds of analyses astronomers hope to do on more Earth-like planets—those similar to ours not just in size and temperature but also atmosphere-to-planet ratio. One of the problems with planets like WASP-43b (and our own Jupiter, for that matter) is that they are shrouded in a thick envelope of gases. Whatever solid surface it may have sits far below, so even if it resided in a less scorching orbit, it wouldn't be habitable. It's why astronomers are re-aiming their atmospheric analyses to super-Earths—to

date, the smallest exoplanets found in any significant number.

KREIDBERG, FOR ONE, HAS been sniffing around these worlds. She and her team used the Hubble to solve a long-standing question about the atmosphere of one known as GJ 1214b. Charbonneau and his group discovered the exoplanet in 2009, but they couldn't tell if it was surrounded by an extended, gassy atmosphere like, say, Neptune's or a more compact one like Earth's. Kreidberg watched the starlight—specifically, how it was altered as it filtered through the planet's atmosphere.

But what she saw was no alteration at all. It was both an unusual result and a common one. "Astronomers threw the kitchen sink at this planet for three years after its discovery," says Kreidberg, implying that none of them had had any luck breaking its code. The reason for everyone's trouble, she realized, was that the planet's atmosphere is filled with clouds, maybe made of potassium chloride or zinc sulfide, but in any case dense enough to keep any starlight from escaping.

A team led by Caltech's Heather Knutson encountered the same issue as they did an atmospheric analysis of another super-Earth, GJ 436b. "Clouds are cool in their own right," Knutson says, "but they can be frustrating."

In fact, it was getting so that planet hunters were beginning to fear that most, if not all, smallish planets were shrouded by clouds. Then, in September 2014, a University of Maryland team led by Jonathan Fraine detected water vapor in the atmosphere of HAT-P-11b. (Names of stars and exoplanets often refer to the survey that found them, which is why they can seem so different and random.) This time it wasn't the water vapor that was the important discovery; rather, it was that a relatively cloud-free world close to Earth's size existed. Once one was found, scientists were confident they would uncover more.

A series of observations carried out by MIT's Brice-Olivier Demory and his team affirms Fraine's discovery. Their target was Kepler-7b, one of the first planets discovered by the Kepler space telescope after it launched in 2009, and to see it they looked not at starlight passing through its atmosphere but at light coming off the planet itself. Surprisingly, the brightness of the planet just before it ducked behind the star was distinctly different than its brightness when it emerged on the other side. Demory's conclusion: one side of 7b, and only one side, is shrouded in cloud cover. "It is becoming apparent that a number of these planets across the board, from hot Jupiters down to super-Earths, seem to be hosting clouds or hazes of some kind," says Nikku Madhusudhan, an expert on planetary atmospheres at

Yale. It's just as apparent that those clouds differ in concentration and makeup from one world to the next.

Of course, there is much more work to do on exoplanet atmospheres. Madhusudhan, for example, recently measured water in three hot Jupiters and found them to be astonishingly dry. "This opens a huge can of worms," he said in a statement released by the Hubble Space Telescope Science Institute. "We expected all of these planets to have lots of water in them." The finding sent theorists back to reconsider their models.

As the pace of exoplanet atmospheric analysis continues to accelerate, what nobody needs to reconsider is its usefulness. It isn't about to reveal alien life to us (not with our current telescopes, at any rate). But what it has taught us—and promises to continue to teach us—about the "air" way up there has surely pointed us in the right direction.

E.T., Are You Calling Us?

The discovery of earth-size planets has scientists more confident than ever that we are not alone. But the search isn't cheap, and unless we find the money to fund it, alien attempts at contact will fall on deaf ears

BY MICHAEL D. LEMONICK

THESE DAYS, though technically retired and despite ongoing funding challenges, SETI founder Frank Drake continues his life's work. His latest interest is the possibility of life on planets that orbit red dwarf stars.

FROM ITS VERY BEGINNINGS MORE THAN SIX decades ago, SETI, the Search for Extraterrestrial Intelligence, has been a science fueled by hopes and dreams but not a particle of solid evidence. A young astronomer named Frank Drake launched the field with what he called Project Ozma in 1960 by pointing his radio telescope at the star Tau Ceti in an effort to detect an alien broadcast signal. But neither he nor anyone else has ever verified a single peep from an extraterrestrial civilization.

No one even knew back in the 1960s whether planets existed beyond our own solar system—or, if they did, whether they had given rise even to primitive life, let alone to beings who could beam radio waves trillions of miles across the vast emptiness of interstellar space. And if they had, who could say for sure that those beings used radio for communication? The odds seemed so long that Drake would advise young scientists interested in SETI to do other research as well, so they'd have a better chance of actually discovering something. Otherwise, he felt, they could get too discouraged.

But plenty has changed since those early days. We know there are lots of planets orbiting other stars, many of which, to everyone's astonishment, are much smaller and redder than our sun—in other words, places nobody had considered before.

It's clear that we are seeing only the tip of the cosmic iceberg. "This is revolutionary," says Jill Tarter (the real-life inspiration for Jodie Foster's character in the film *Contact*), the recently retired director of the Center for SETI Research, part of the nonprofit SETI Institute, in Mountain View, Calif. "Now we can point our telescopes at stars where we know planets exist."

NOT ONLY THAT: THE ELECTRONICS that SETI searchers now have at their disposal have seen the same transformation that packs more data-processing power into your smartphone than there was in a room-size 1960s-era computer. "We've got much more powerful receivers," says Drake, who is 84 and technically retired, though he hasn't slowed down a bit. "It's routine now to search through 100 million radio channels at once using cheap off-the-shelf components."

In 1998, moreover, searchers began looking not just for radio signals but for the bright flashes of alien lasers in what's now known as Optical SETI, or OSETI. "On Earth," says planet-hunting legend Geoff Marcy of the University of California, Berkeley, "we've now got lasers that can emit more than a petawatt [a quadrillion watts] of power for up to a nanosecond. They're so bright they can outshine a star." Presumably any self-respecting alien civilization would have something similar—and similarly bright.

With this expanded search strategy, more-powerful detectors and a better fix on which stars to target, you might assume that we've finally entered the golden age of SETI, especially since the 2007 debut of the Allen Telescope Array (ATA) in northern California, the first radio installation built expressly for SETI. Before the Allen, searchers had to compete for time on existing radio telescopes.

THE IDEA OF ET LIFE is no longer so far-fetched. We know that there are planets orbiting other stars—more than 1,000 have been confirmed since 1995. It's clear that this is merely the tip of the iceberg, and that the discovery of a true Earth-like world is probably not far off. "This is revolutionary," says Jill Tarter. "Now we can point our telescopes at stars where we know planets exist."

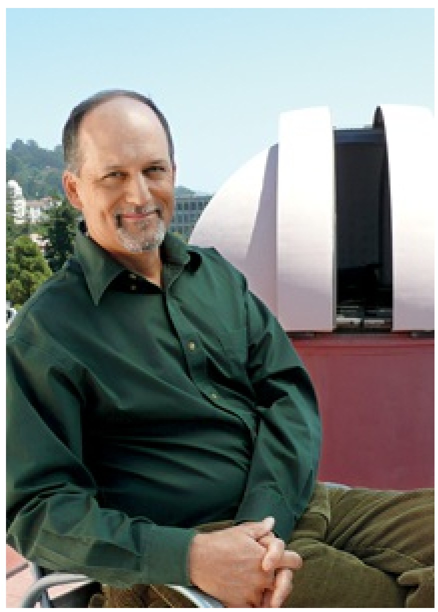
But for all the many things going right with SETI, one shadow has hung over the program for much of its existence and is looking more ominous than ever: a terrible shortfall in funding. For a while back in the 1980s, NASA was putting a fair amount of money into SETI—naturally enough. But in 1993, Nevada's Sen. Richard Bryan, declaring that "not a single Martian has been found," introduced an amendment cutting off all NASA support. "He was trying to make a name for himself as a budget hawk," says Drake ruefully.

Jill Tarter

Since then, the search has depended on private money. "We were getting donations from people like Bill Hewlett and Dave Packard, the founders of Hewlett-Packard," says Drake, "and Gordon Moore, the co-founder of Intel, and

Paul Allen, the co-founder of Microsoft. Paul Allen gave $30 million for the Allen Telescope Array." But Hewlett and Packard passed away, and when the economy tanked in 2008, says Drake, fortunes worth $30 billion were suddenly worth only $20 billion. Overall, private funding has plummeted dramatically.

JODIE FOSTER played a character in the movie *Contact* that was based on Jill Tarter.



GEOFF MARCY, an astronomer at U.C. Berkeley, has discovered more exoplanets than anyone else in history.

Berkeley, meanwhile, which had agreed to fund the ATA's operations if the SETI Institute raised the money for construction, went through its own financial crises; it too pulled back, and the telescope had to go offline in 2011. "If you think of SETI as not just research but exploration," SETI Institute senior astronomer Seth Shostak said at the time, "this is like sending Captain Cook to the South Pacific but not giving him any food or supplies." Thanks to a fund-raising campaign, the array's 42 radio dishes were brought back to life in 2013, and the Air Force has

bought some of the telescope's time so it could keep tabs on orbiting space junk.

But money is still very tight, and Tarter stepped down from her position in part because she wanted to devote more time to bringing in desperately needed cash. "It's a dramatic juxtaposition," says Marcy, "between a compelling science quest and an utter lack of resources." That's not only true for the SETI Institute but also for the handful of other small-scale searches going on in the U.S. and in a half-dozen other countries, including Italy, Argentina and Japan.

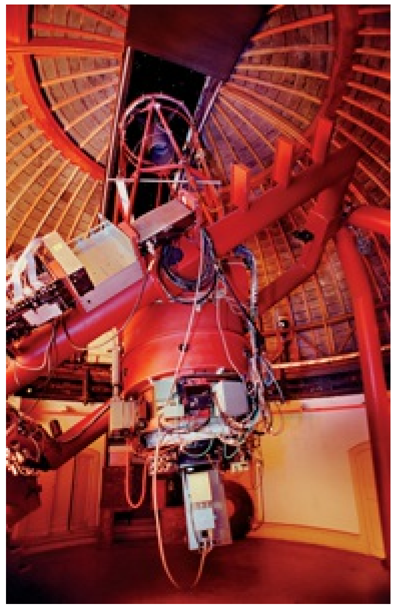
Perhaps the private sector has gotten tired of SETI, Marcy speculates, or maybe it's just too difficult to overcome the "giggle factor" that has dogged the search right from the beginning; that's understandable enough, given the public's long-term exposure to UFO nuts and outlandish sci-fi movies. Or maybe, he says, the public needs a more inspiring proponent. Says Drake, "Anytime I've done anything in the media, I've hoped it would stimulate interest. But [the late] Carl Sagan," an early and enthusiastic SETI booster, "was a lot more eloquent."

Given SETI's money woes, you might expect its proponents to think about giving up. But that's clearly not happening. Marcy, for example, is eager to ratchet down his planet-hunting research so he can get more deeply into SETI himself. For him, the possibilities are just too enticing. "We now know that there must be Earth-size planets in their stars' habitable zones," he says, and once you have a rocky planet with plenty of water and lukewarm temperatures, "the biochemistry of life is a foregone conclusion. Yes, intelligent life is another matter, but life is more or less a done deal."

That being the case—and assuming primitive life gives rise to intelligence at least some of the time—Marcy has begun his own modest search, trolling for evidence of extraterrestrial lasers. He's not simply watching for flashes of light, however. He's using a spectrometer, which smears starlight into the rainbow of colors it is made of. A laser, in contrast, emits one very specific color of light (the first ones were red, but lasers now come in green, violet, yellow and blue—hence the term "Blu-ray"). If an alien civilization was flashing lasers at us, the color of the lasers would show up far brighter than the rest of its star's colors. "The spectroscopy we do of stars during our planet searches," says Marcy, "is amenable to this technique. My plan is to go back to all of our observations and look for these colored SETI dots."

HE'S GOT ANOTHER IDEA AS well. "This is clearly harebrained," he says. "But think of what happens when you point at the nucleus of another galaxy.

You're now seeing 50 billion stars at once—it's the metropolitan downtown area." You're also looking millions of light-years away, too far for a conventional laser to be visible. But in a few rare cases, extraterrestrials might be so advanced that they can tap into the energy of the giant black hole that lurks at every galaxy's core. "If so," says Marcy, "they could power truly amazing lasers, visible halfway across the universe. We've already taken spectra of 35 or 40 galaxies, looking for this effect, and I'm serious enough that I've applied for more telescope time."



LICK OBSERVATORY'S Anna L. Nickel telescope allows scientists to detect as-yet-undiscovered nanosecond laser pulses from beyond our solar system.

Others want to look for laser-flashing aliens in a different way. As an undergraduate at the University of California, Santa Cruz, a little over a decade ago, Shelley Wright got her initiation into SETI working on an optical search project with Frank Drake. Now on the faculty of the University of Toronto, Wright—perhaps mindful of Drake's warning to young scientists—works on other problems in astrophysics, such as the evolution of galaxies, but she has never lost her passion for SETI. Thanks to some funding she got with Marcy's help, Wright is designing a detector that can pick up bursts of infrared light.

ONE REASON FOR CHOOSING infrared is that many stars shine more dimly in the infrared spectrum than they do in visible light. A conventional visible-light laser might be 1,000 times as bright as a star, bright enough, observes Drake, that—if our eyes could detect pulses as short as a nanosecond—"you could literally sit in the backyard at night and see extraterrestrial beacons, if they were there." But an infrared laser, according to Wright, could outshine a star by a factor of 10,000:

“We won’t be looking for a needle in a haystack,” she says. “We’ll be looking for a fire.” An even bigger advantage, she explains, is that infrared light is much better than ordinary light at shining through clouds of interstellar dust.

“We” still includes Drake, who stopped following his own advice about working on anything other than SETI many years ago. He’s collaborating with Wright on her infrared detector, for example, and he’s also thinking about new projects that he and his colleagues might undertake if they could get their hands on more funding. Military radar, for example, deliberately hops from one radio channel to another in a random sequence, so it can’t be jammed. If aliens were doing that with their signals, says Drake, “we couldn’t detect that. The problem could be solved, but it takes more hardware.”

Drake also wants to look backward. “There have been hundreds of searches since 1960,” he says, “and many have reported candidate signals, but when people went back to look, there was nothing there.” Drake and others suspect that at least some signals might have been real, but that by the time of the follow-up observations, which often came days or weeks later, the possible aliens had aimed their beacons elsewhere.

AT ARECIBO OBSERVATORY in Puerto Rico, an intermediate-frequency rack reads telescope signals—and sends a message of its own.

The most celebrated of these missed opportunities was the so-called Wow! signal. In 1977 an antenna in Ohio tracked a radio blip for more than a minute that seemed as though it could be from alien broadcasters. Unfortunately, scientists didn’t notice the signal in the telescope’s computer output until several days later.

An Ohio State astronomer wrote “Wow!” on the printout—but the signal never repeated. “We need to have equipment set up in such a way that we can do immediate follow-ups,” says Drake. The SETI Institute recently created an online program called SETI Live, which lets ordinary citizens monitor the Allen Telescope Array’s computers for signals that merit follow-up. But that’s not nearly enough. “We need to increase funding,” he says, “so that we’ve got personnel ready to leap on a promising signal.”

All of these ambitious searches, like Drake’s very first during the last days of the Eisenhower administration, make one key assumption: There’s someone out there. But in fact there’s another assumption that often goes unmentioned: in order for a radio or a laser signal to be detectable across tens or hundreds of light-years, it has to be aimed more or less right at Earth. “It would have to be intentional,” he says. And because communication between the stars is expensive in terms of both hardware and energy—and also because it wouldn’t be likely to benefit the aliens—it would have to be altruistic. “This raises the question,” says Drake, “of whether altruism is widespread or whether it’s a rare thing.” Maybe humans are freaks for being altruistic even some of the time. “My own opinion,” he says, “is that it’s probably widespread, because it would be selected for by evolution.”

Whether humans are curious enough to spend more money to find out, however, is perhaps an even greater unknown. Says Marcy, “SETI has to become a major effort in the 21st century. It has to rise into the center of the radar screens of NASA, the National Science Foundation, the European Space Agency.”

The truth, in short, is out there. But it will take a bit more cash to learn what it is.

SETI Warriors

A Visit to the Home of the ET Seekers

And what if someone is trying to dial us up long distance? Who will take the message? Most likely one of the researchers at the SETI Institute in California. In the meantime, though, they're not just sitting around waiting for the phone to ring.Inside the inner sanctum of Mission Improbable

BY BRITTANY SHOOT

SETI'S ALLEN TELESCOPE ARRAY, at the Hat Creek Radio Observatory in Northern California, is an LNSD (Large Number of Small Dishes) array. Its first 42 antennas went online in 2007; upon completion, there will be 350 in all.

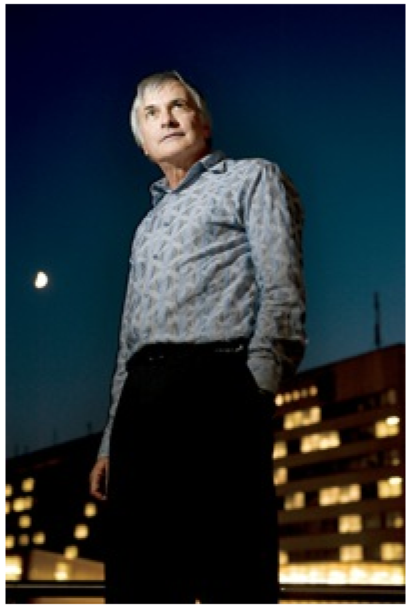
"E.T. DIDN'T SEND AN EMAIL OR A FAX," SETH SHOSTAK jokes in his rather ordinary office on a relatively ordinary weekday afternoon. Shostak, though, is no ordinary guy, and he most definitely has no ordinary job. He is the senior astronomer and director of the Center for SETI Research, one of the three divisions in Mountain View, Calif., that make up the SETI Institute. SETI stands for "search for extraterrestrial intelligence," and on this particular ordinary day, Shostak, who has a Ph.D. in astrophysics from the California Institute of Technology, is explaining two necessary conditions for engaging in his extraordinary line of work. To find intelligent extraterrestrial life, one must (1) be open to the possibility that it exists and (2) actually look for it. This is exactly the no-nonsense explanation you'd expect from a man who has spent his career trying to get a grip on the unfathomable.

Contacting aliens has long occupied a particularly active niche of American

popular culture—think Roswell and *War of the Worlds, Close Encounters* and *E.T.* —and these days, SETI is walking point on the expedition. But make no mistake: the SETI Institute, which was conceived in 1984 and opened for business in February of the next year, is not concerned with pulpy UFO mythology. Its arena is hard science, the kind that will be the basis of any future communication with life beyond Earth.

The mission has its origins in the previous century. In the 1960s, astronomer Frank Drake pioneered the first major SETI foray: Project Ozma, the goal of which was to pick up any interstellar radio waves. A little more than a decade later, SETI programs were established by NASA at its Jet Propulsion Lab and Ames Research Center. But since those gung-ho beginnings, the pursuit, if not the interest, has stagnated a bit. SETI's battle, these days, is as much uphill as skyward. "As a nation, we're not as excited as we used to be," Shostak says. "And that's too bad, because space is more accessible."

Although the SETI Institute does out-of-this-world work, the actual offices are quite humble. It is housed in a nondescript, two-story, beige building off the split highway that bisects downtown Mountain View, the heart of Silicon Valley. And even that is more building than the institute requires; it rents out half to a cloud-computing enterprise. In addition to the research center, the institute comprises the Carl Sagan Center for the Study of Life in the Universe and the Center for Education and Public Outreach. Despite its far-reaching name, the former brings together astrobiologists and astrophysicists to understand habitability in our solar system and even extreme spots here on Earth. At the helm is David Morrison, a former senior NASA manager and one of the founders of the field of astrobiology. The Center for Education and Public Outreach works to make SETI accessible to students of all ages and applicable to a wide variety of disciplines and fields.



SETH SHOSTAK of the SETI Research Center speaks daily with amateurs sure they've seen an ET.

Look closely, and you'll notice that the taupe carpet in the lobby contains a wide cerulean and celestial swirl, and the orb lamp that hangs over a kidney-shaped table is decked out with a few Saturn-style rings. Beyond the entrance, camel-colored cubicles are scattered with suitably scene-setting accessories: globes of Venus and Mars, a model of the Allen Telescope Array—the institute's pride and joy—and a tabletop version of Go, the ancient Chinese board game. But these touches are all that indicates something otherworldly is going on here.

THE SETI INSTITUTE, with headquarters in Mountain View, Calif., has some 150 employees.

Actually, at times the question is whether it will be going on much longer. The institute's future is a perpetually precarious one. Congress initially funded the institute through NASA, but that support was fleeting. Shostak, in fact, vividly remembers watching C-SPAN on the day in 1993 that the vote to defund the institute was held. The financial breakup didn't exactly come as a surprise. With the money for space-related work chronically tight anyway, supporting the search for alien intelligence is just the sort of polarizing stance that many members of Congress can't afford to take.

And that remains even more true today. Still, Shostak continues to fight for the institute, traveling often to Washington to testify in support of his colleagues' work. Meanwhile, covering the shortfall means relying on partnerships with institutions that have similar goals—for instance, the National Science Foundation, the National Radio Astronomy Observatory and any of a number of prominent universities.

AS DIRECTOR OF THE RESEARCH center, Shostak—or "setiguy," as his license plate declares—bears much of the responsibility for fund-raising. After more than 20 years at the SETI Institute, he is in an office reliably filled with spaced-out ephemera, photographs he's taken of telescope arrays and posters from projects he's worked on over the years. One towering metal shelf holds rows of plastic binders, in each one a movie script he was asked to review.

Shostak says he's not nearly as concerned about the scientific accuracy of any particular film as he is with the ability of film in general to turn hearts and minds in his favor. In the end, he figures a space shuttle that hums as it glides across the screen isn't about to kill the space-traveling dreams of any child who knows

enough to know sound doesn't travel through the vacuum of space. The issue is actually the opposite: Does the movie portray science in a way that will get viewers fired up enough—as they were, say, 50 years ago—to urge further exploration?

Of course, there are many people who think the search is already over. And they remind Shostak of that constantly. He fields at least one call a day and several dozen emails a week from UFO enthusiasts who claim to have spotted something definitive in the sky. "In the old days, I think they had my name and number on a Post-it at the NASA switchboard," he says with a smile. "Aliens? Call Shostak." These days, the well-meaning and reality-challenged alike can simply send links to their amateur videos, often some shaky handheld footage of a bright light hovering on the horizon at dusk. Based on this "evidence," the correspondent will maintain that he has once and for all found the proof that the good people at the institute have long looked for. And each time, Shostak patiently explains why what has been recorded is almost certainly something much less dramatic, probably Venus or some bright star. If he isn't politely crushing someone's conviction, he is defending the federal government, pointing out that the powers that be have neither the resources nor the motivation to cover up an alien encounter. But that's as far as he goes. People who believe are steadfast. "It's like a religion," he says. "You can't change minds."

His time is better spent producing *Big Picture Science*, the institute's syndicated radio hour, which covers a wide range of topics, from bioengineering and stem-cell therapy to important inventors in astrophysics and computing. There's also the occasional "Skeptic Check" episode, to explore potential flaws in scientific findings or debunk pseudoscience that has been disseminated as truth. In the studio, a generic and dimly lit room layered with soundproofing foam, Shostak sits at a desk surrounded by chairs meant for co-hosts and guests and by shelves stuffed with books like *Paleofantasy and Cracking Particle Code*, left behind or sent in by past and potential show guests. The show is about to begin. "Come in, Earth," Shostak murmurs into his microphone as a test.

If the SETI Institute is characterized by any particular thing, it is the larger-than-life equipment there that aids the residents in their search. The most notable of its massive setups is the Allen Telescope Array, an LNSD (large number of small dishes) set of what will eventually be 350 six-meter antennas. LNSD arrays are more efficient and affordable than the antennas traditionally used in radio astronomy. This one is the brainchild of Drake, but it was named for Microsoft co-

founder Paul Allen, who has donated more than $30 million to the project so far.

BIG PICTURE SCIENCE is a weekly radio show produced by this SETI team, including Shostak, far right.

BUT THE INSTITUTE HAS ALSO enlisted a fair amount of outside help for its core mission. The SETI@home project, launched in 1999 and operated by the University of California, Berkeley, is one of the organization's better-known efforts to involve the public in the search for life beyond the Milky Way. When SETI researchers began using radio telescopes to listen for narrow-bandwidth signals from space, they ran into a computing power problem. It caused them to turn to the public to pool resources. Volunteers around the world now donate their unused computing power to the institute by downloading a simple program that allows their personal computer's extra bandwidth to be used to cover greater frequency ranges with heightened sensitivity.

But while many amateur stargazers have assisted the institute over the past three decades, in general the public's understanding of SETI can be a bit limited. Some people, for instance, think the institute broadcasts its own calling-card signal into space. That is not true, because it would take an amount of money, equipment and time that the researchers simply do not have. Instead they must content themselves with diligently monitoring what they pick up passively over millions of radio channels.

That is, those whose job it is to listen. In fact, most of the research at the SETI Institute isn't concerned with keeping an ear out for ET communiqués. In fact, Shostak says, nine of every 10 colleagues at SETI are involved in what could be considered non-SETI work. (The institute has about 150 employees in all.) "More people here work on Mars and outer solar system moons," he says. In short, much of the research—from the hydraulic history of Mars to the life history of space rocks to the discovery of exoplanets—is concerned with looking for evidence of life of any sort, not intelligent life specifically. They are looking, that is, for the kind of

life that isn't likely to be sending sophisticated messages into the cosmos.

THE SETI@HOME project allows volunteers to help analyze radio telescope data on their computers.

In a cozy corner office with a view of a series of squat peaks in the distance, planetary-rings specialist Mark Showalter always seems to be on his way to somewhere else. Between his on-site research and many speaking engagements, he's on the road much of the time. Showalter is perhaps best known for discovering three planetary rings, including Jupiter's two outermost gossamer rings, and six moons, including two orbiting Uranus—Cupid and Mab—and Pan, the walnut-shaped moon hidden amid Saturn's rings. His observations have pushed the conception and understanding of the formation of planets, secondary satellites and even entire galaxies. What does any of that have to do with SETI? The creation of the heavens and the creation of life are very much intertwined.

Similarly, relative SETI newcomer Michael Busch is interested in comets and asteroids. Both are invaluable time capsules from the origin of the solar system. Studying their raw materials and chemical makeup can help us better understand the seeding ingredients of life.

As you walk the floor of the SETI Institute, one thing becomes very clear. This place is filled with unquestionably serious men and women involved in the most quixotic of endeavors. But though it might seem an awfully isolating path, it is also very clear that they are just people doing a job as they live their very human lives. Amid the beige office partitions, a dazzling light beams from one small square. Neil Heather is happily perched in front of a nearly blinding lamp. Heather is a researcher and webmaster who works with Showalter in the NASA-funded four-member working group that catalogs, archives and distributes data relevant to planetary rings systems. Heather doesn't have a vision problem; the brightness is his way of combating seasonal affective disorder. Among his scientifically stalwart colleagues, his alternative therapy is regarded with a kindly side-eye, as are the other

life hacks he employs to combat his wintertime mood. (In case you're curious: lowering carbohydrate intake and getting up at the same early hour each day, including weekends, seem to help too.)

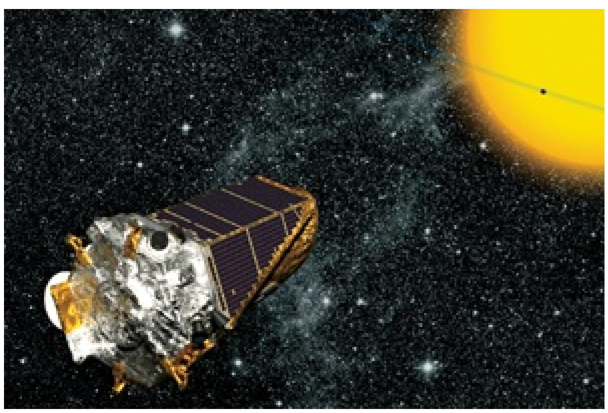
As I follow the light and peek into Heather's office, I comment on the range of small experiments and accessories that clutter his desk. After Shostak and I continue on down the hall to inspect a model of the Allen array and a towering kangaroo sculpture—homage to Shostak's tenure with telescopes Down Under—Heather catches up to us, a length of copper pipe and super-strength magnet in hand. "Drop the magnet through the tube!" he instructs gleefully. It takes the magnet nearly two seconds to glide through the pipe; apparently the two objects have caused a slowing eddy current inside the tube, something about Lenz's law of electromagnetic currents based on Newton's third law of motion. I clap in wonder as Heather laughs exuberantly. Then he turns and heads back to his well-lit lair.

Spies of the Sky

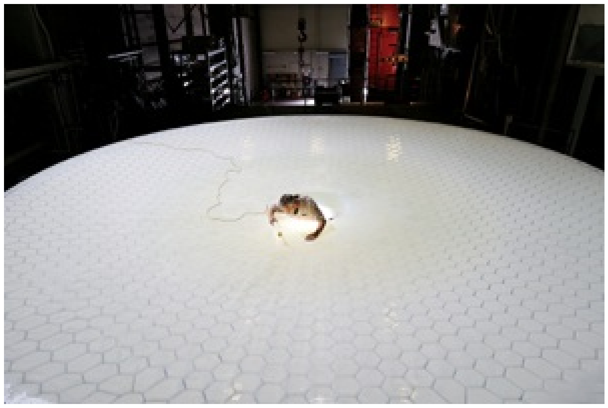
We've come a long way since Galileo trained his homemade telescope skyward in 1609. Today a remarkable array of instruments of unprecedented power and sensitivity are spilling the secrets of the cosmos by allowing stargazers to peer ever deeper into space and time

BY DAVID BJERKLIE

GREAT CANARY TELESCOPE *Canary Islands* Sitting atop a mountain on La Palma, 250 miles off the Moroccan coast of Africa, this is the world's largest single-mirror optical telescope.



KEPLER TELESCOPE The sole mission of NASA's spacecraft is to find planets, and it has found lots of them—1,000 confirmed since its launch in March 2009.



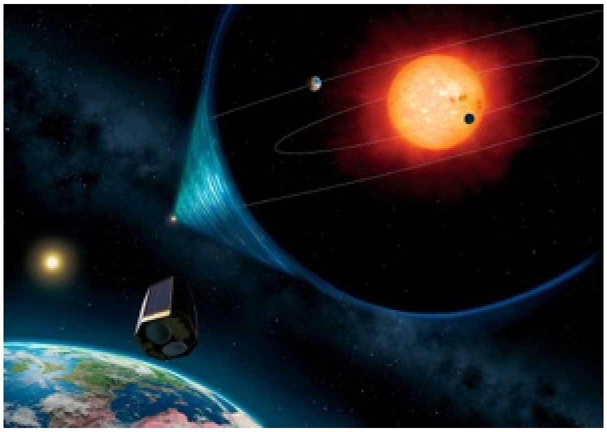
LARGE SYNOPTIC SURVEY TELESCOPE *Cerro Pachon, Chile* The LSST will, when completed, contain the world's largest digital camera, allowing it to trace billions of remote galaxies and track moving objects, including exploding supernovas and asteroids.

KECK TELESCOPE *Mauna Kea, Hawaii* Because they make the most of their large mirrors, adaptive optics and prime site, Keck I and II have been called Earth's most productive telescopes.

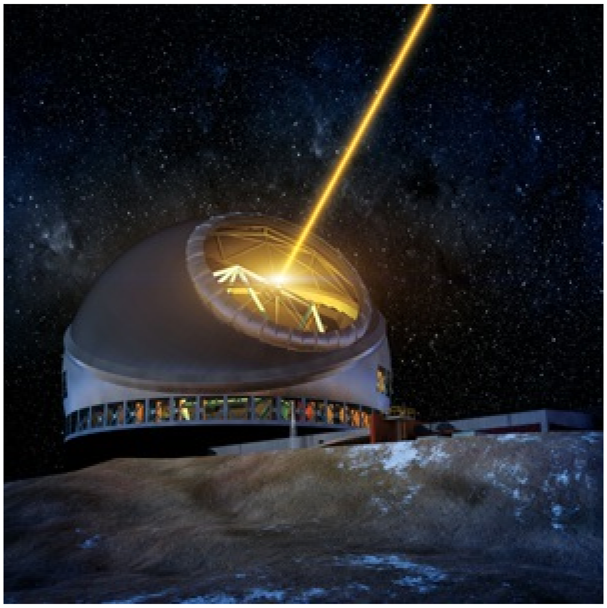
LARGE BINOCULAR TELESCOPE *Mount Graham, Ariz.* Its pair of mirrors offer unparalleled light-collecting power, resulting in images that exceed the clarity of current space telescopes.

TELESCOPES OF THE FUTURE . . .

GIANT MAGELLAN TELESCOPE *Las Campanas Observatory, Chile* An array of seven 27.6-foot mirrors will have a combined light-gathering capacity of up to 10 times as great as any existing telescope's.



PLATO MISSION OBSERVATORY The European Space Agency hopes to launch this space platform in 2024. Its 34 small telescopes and cameras will look for habitable planets that resemble our own.



THIRTY METER TELESCOPE *Mauna Kea, Hawaii* Sharing a mountain with the Keck Observatory, TMT will be the world's largest optical telescope, with a 98-foot mirror, once it's completed.

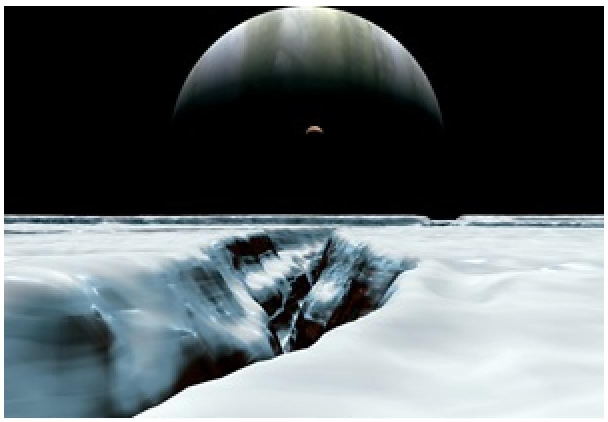
TRANSITING EXOPLANET SURVEY SATELLITE NASA's TESS will monitor the brightness of more than 500,000 stars during a two-year search of planet transits. Its Cape Canaveral, Fla., launch is scheduled for 2017.

Neighborhood Watch

Life in Our Solar System

All those faraway planets that may or may not have life can overshadow a few promising spots much closer to home. From Mars to the moons of Jupiter and Saturn, some scientists are keeping the search local

BY MICHAEL D. LEMONICK



A CRESCENT JUPITER hovers near the horizon along with its volcanic satellite Io. But it's the ice-covered Europa, in the foreground, that is most likely to be hiding the signs of life we are looking for.

PERCIVAL LOWELL DIED NEARLY A century ago, but if he were alive today, he'd be grinning from ear to ear. Not about Pluto, obviously. The tiny world was discovered at the observatory Lowell personally bankrolled in Flagstaff, Ariz., and he'd still be livid about its unceremonious dismissal from the fraternity of planets.

Rather, Lowell would be gloating about other recent outer-space happenings. A staunch believer in extraterrestrial life, he went to his death insisting the "canals" he spied on Mars were the footprint of an agricultural civilization. More-powerful telescopes soon put that misconception to rest; the Red Planet, it turns out, has the thinnest of atmospheres and a surface drier than our driest desert. Martian farmers simply didn't exist.

Over the past couple of decades, however, the idea that life may be thriving just around the cosmic corner in other parts of our solar system has undergone a radical revival. A series of orbiters and rovers have revealed that though Mars is parched today, it used to swim with rivers, lakes and seas that once—billions of years ago, but still—could have made it as livable as Earth.

And that's not all. Space probes have found evidence of liquid water, which

biologists still consider to be essential to life, not just in balmy precincts close to the sun but in the solar system's outer reaches as well.

That's especially intriguing because you'd expect temperatures that never come close to climbing above zero to turn every drop of water to solid ice. Yet space probes from Galileo to Cassini have shown unequivocally that the moons of several giant planets—Jupiter's Europa and Ganymede, Saturn's Enceladus and Titan, maybe Neptune's Triton—contain large subsurface oceans under thick rinds of ice. Even Pluto might have a repository of water deep underground. Each of these places, then, theoretically could host some sort of biology. For that matter, so could Mars—if not on its surface, then in crevices or caves underneath it, where organisms may have retreated as the atmosphere thinned and topside water vanished.

Water alone, of course, does not a Garden of Eden make. For starters, all of the locations listed above are likely utterly dark, cut off from the solar energy that powers virtually all life here on Earth. They may also be contaminated with salts, acids and other chemicals that are toxic to humans and a vast number of known organisms.

A vast number, though, is not all. Starting in the 1980s, biologists began to realize that life can survive—even thrive—in the harshest conditions. Bacteria, at the very least, have been found in hot springs, in solid rock a mile underground; in lakes deep beneath the Antarctic ice sheet; in radioactive-waste storage pools and clustered around super-heated vents on the seafloor. "That there's a subsurface biosphere on Earth," says Princeton astrobiologist Christopher Chyba, "makes subsurface biospheres plausible elsewhere."

EXOMARS ROVER, developed by the European Space Agency, is set to land on Mars in 2018. It will hunt for fossil proof of biological processes.

Plausible, though, is not proven. But it is extraordinarily exciting. The search for life on other worlds, particularly those we have a reasonable chance to get to, has motivated NASA's missions for decades. Several of the key experiments aboard the first-generation Viking landers that set down on Mars in the 1970s were designed to look for metabolic byproducts of Martian organisms.

One of them even picked up something tantalizing. "It looks at first indication very much like biological activity," Viking scientist Harold Klein told TIME in August 1976. Most scientists now believe that what was found were remnants of an inorganic chemical process. Gilbert Levin, though, the man in charge of the experiment, continues to maintain that Viking discovered life.

In any case, it was more than enough to pique NASA's interest. Since then, the space agency has pursued life on Mars in a consistent and deliberate fashion. Over the past several years, orbiters and rovers have found more and more evidence that water once pooled on the planet's surface. They've also shown that bacteria, if they ever existed, could have derived nourishment from chemical reactions between minerals in Martian lakes and seas, just as the bacteria known as chemoautotrophs do on Earth. "This environment would have been almost Earth-like in terms of geochemistry and in the presence of water," Caltech's John Grotzinger, a project scientist for NASA's Curiosity rover, told TIME in 2013, referring to Gale Crater, where Curiosity still pokes around.

ENCELADUS, Saturn’s sixth-largest moon, has been orbited for more than a decade by the unmanned spacecraft Cassini. In 2014 NASA reported that Cassini had discovered evidence of a large underground ocean of liquid water.

Finding life itself is another matter entirely. Given that the ideal living conditions evaporated from the Red Planet, along with its atmosphere and surface water, a long time ago, any hints of biology we may find are likely to exist in fossil form only. So NASA is considering another rover trip to Mars around 2020, this one to collect rocks and soil from whatever places seem as if they might have sustained life. The European Space Agency, meanwhile, is partnering with Roscosmos, the Russian Space Agency, on a rover expedition slated to land in 2019. It will drill seven feet down, to an environment protected from the sun’s harsh rays, to search for telltale biological signs.

Solid evidence from any of these missions will bring us a step closer to confirming an intriguing premise. “If there was an early, clement period followed by increasingly crappy conditions,” says Penelope Boston, an astrobiologist at New Mexico Tech University, “then life could have retreated deep underground.” In particular, it may have colonized caves, of which Mars has plenty.

BRUIE, NASA's new Buoyant Rover for Under-Ice Exploration, crawls along the underside of the surface ice in a test in Alaska's Sukok Lake

Even that, however, would be just a beginning. Because finding life on Mars, past or present, won't prove it arose there. Scientists know asteroid impacts on one planet can blast rocks into space that fly off to another. Who's to say life on Earth didn't hitch a ride to Mars and seed it?

In reality, Mars's weaker gravity makes the opposite trip more likely; pieces of Mars have already been unearthed here. The "discovery" of fossil bacteria inside a Martian meteorite in the 1990s was a false alarm, but it didn't dissuade scientists from thinking such life could survive the trip. Either way, should we learn that Martian biology is built on the same DNA as our own, we'll be fairly sure one of the planets was the source of life on both.

The origin story in the outer solar system will be much clearer. Any life that may have grown (or grows) on Europa, Enceladus or another distant world would almost certainly have sprung up independently. The chances of a bacteria-laden rock making so long a journey are close to zero. Luckily, these bodies possess all the ingredients of life, including water and organic chemicals.


A prototype cryoprobe that would melt through Europa's ice, several kilometers thick, to the water below.

Seekers of life, though, must deal with a different problem out here. Whatever evidence of biological activity there is will be buried under a layer of ice tens of miles thick, at minimum. To get to the bottom of things, scientists will have to melt through the ice with lasers or some other heat source, then deploy diving rovers to explore below.

Originally, engineers imagined high-tech submarines, something like the remotely operated rovers that marine biologists use to comb Earth's oceans. But a team at NASA's Jet Propulsion Laboratory (JPL) is working on a craft that makes far more sense. Known as the Buoyant Rover for Under-Ice Exploration, it floats up to the underside of the ice, then crawls along it, fishing for life-forms that might gather there or for waste gases left behind by them.

"It's far more efficient," says Kevin Hand, an astrobiologist at JPL who is a member of the team pursuing the concept. "A swimming vehicle has to move in three dimensions and fight against currents, whereas the under-ice rover just needs to cling to the ice." The JPL scientists already know their submersible is viable: a prototype has been successfully deployed in shallow lakes in Alaska.

Long before any craft goes to work for real, however, planetary scientists need to do the same sort of meticulous reconnaissance they did on Mars, isolating the most promising landing spots on each of these faraway bodies. And that remains a future task. For Europa or Ganymede, that information may have to come from the European Space Agency's Jupiter Icy Moons Explorer (JUICE) mission, which isn't slated to begin poking around the Jupiter system until 2030. That's because

NASA's own probe, Europa Clipper, hasn't even been funded.

Nor has a follow-up mission to Saturn's moons, which some believe offer even better targets. Says JPL scientist Carolyn Porco, who works on the Cassini mission now exploring Saturn's system, "It's imperative we go back." Enceladus, for example, boasts an important advantage over Jupiter's Europa: its ocean spits some of its contents into space by way of massive geysers. Imagine if we knew what those plumes held. Thing is, it wouldn't be hard to find out. "You land, stick out your tongue, and get what you paid for," Porco says. So it's a shame we aren't planning a return.

All of these projects, of course, presume we're looking for a familiar version of life. Some astrobiologists speculate that another of Saturn's moons, Titan, may have an entirely different kind, lurking not in oceans deep belowground but in lakes of methane and ethane on the surface. Problem is, it's easy enough to conceive such a thing but much harder to hunt the quarry. "The dilemma," says Chyba, "is what kind of experiment do you do to look for life that's different? Life could well have a very different chemical basis, but our ignorance is so great that I think it's reasonable to defer it as an astrobiological target."

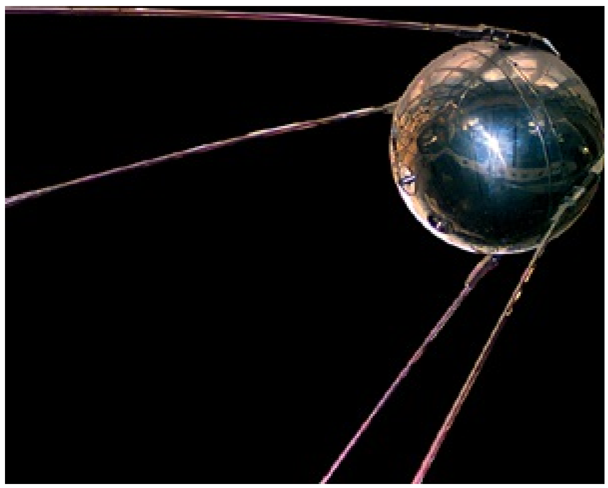
That's OK. With so many other promising places to explore—a range of close-enough habitats that would make Percival Lowell's jaw drop—we have plenty to keep us busy.

Discovery Channels

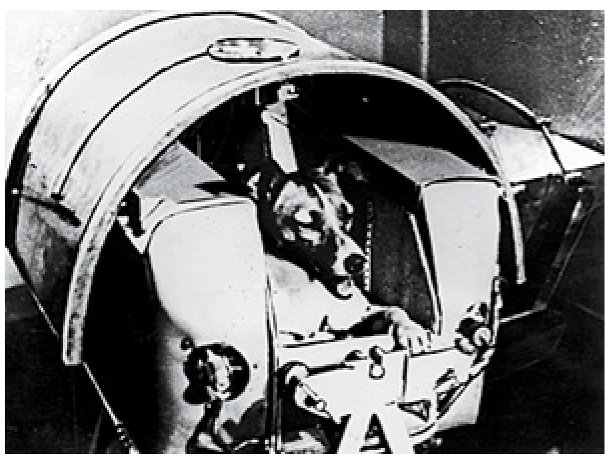
60 years on the trail of ET

By David Bjerklie

1957



OCT. 4, 1957 *Soviets launch Sputnik 1, first man-made object to orbit Earth*



NOV. 3, 1957 *Sputnik 2 carries the dog Laika, Earth's first animal in space*

1958

JAN. 31, 1958 *U.S. puts satellite Explorer 1 into orbit*

APRIL 9, 1958 *NASA names seven pilots to the original U.S. astronaut corps*

1960

1960 *First ET search, Project Ozma, begins at the National Radio Astronomy Observatory*

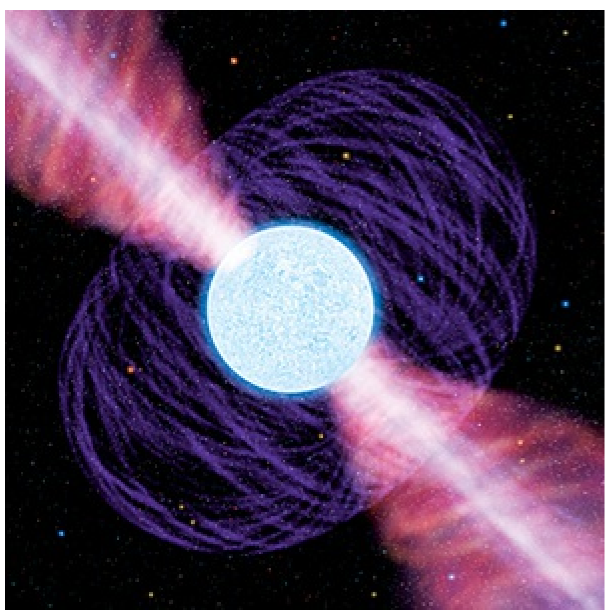
1961

JAN. 31, 1961 *U.S. sends Ham, a chimpanzee, into space, paving way for humans*

APRIL 12, 1961 *Soviet cosmonaut Yuri Gagarin is first man in space*

MAY 25, 1961 *President John F. Kennedy declares goal of landing a man to the moon*

MAY 5, 1961 *U.S. sends first astronaut, Alan Shepard, into space*



1961 *Detection of regular signals from pulsars causes ET false alarm*

1962

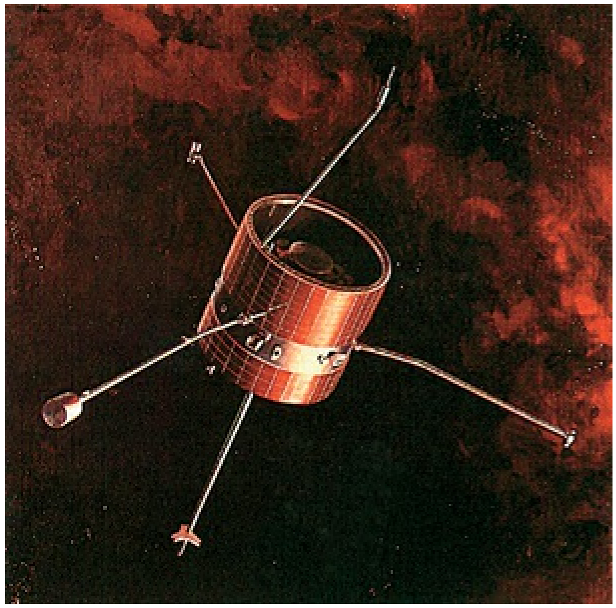
FEB. 20, 1962 *John Glenn is first U.S. astronaut to orbit Earth*
JULY 22, 1962 *First of 10 Mariner missions to Mars, Venus and Mercury (three fail)*

1963

JUNE 16, 1963 *First woman in space: Soviet cosmonaut Valentina Tereshkova*

1965

MARCH 18, 1965 *Cosmonaut Aleksei Leonov walks in space*
JUNE 3, 1965 *Ed White performs first U.S. space walk*
JULY 14, 1965 *Mariner 4 takes first photos of another planet, Mars*



DEC. 16, 1965 *First in a series of Pioneer spacecraft missions to explore the sun, the asteroid belt, Jupiter, Saturn and Venus*

1969

JULY 20, 1969 *Apollo 11 moon landing. Historic footsteps of Neil Armstrong, Buzz Aldrin carried on live TV*

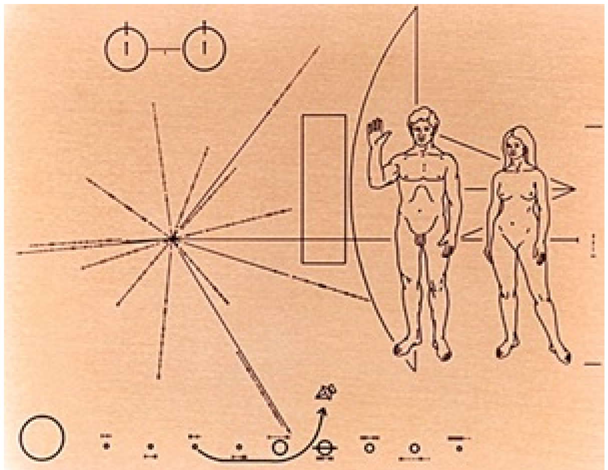
1970

DEC. 15, 1970 *The Venera 7 (one of many Soviet missions to Venus) makes first soft landing on another planet*

1971

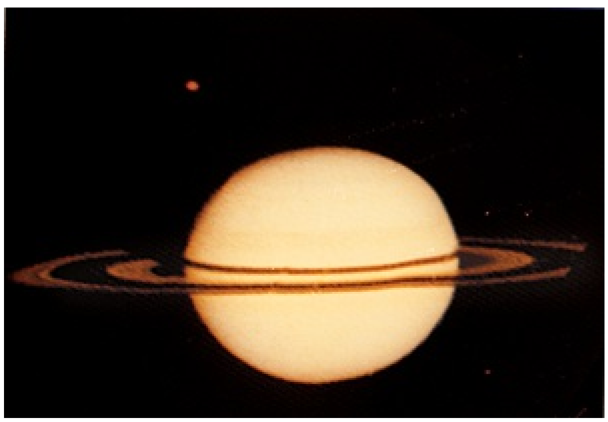
APRIL 19, 1971 *Soviets launch first space station, Salyut 1*
JULY 31, 1971 *Debut of lunar rover vehicle dubbed the "moon buggy"*

1972

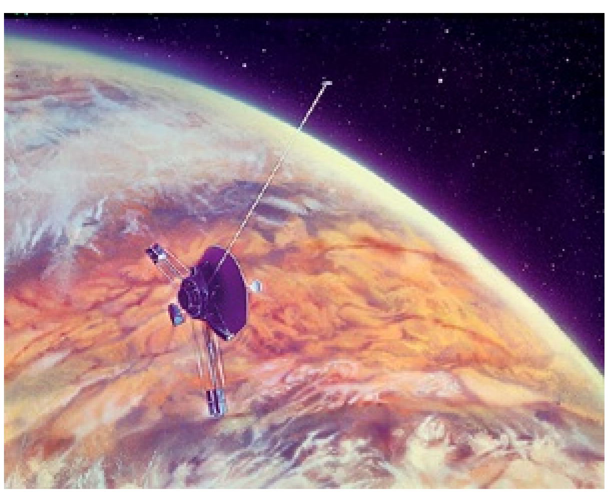


1972–73 *Pioneer 10 and Pioneer 11 space probes sent up with info plaques about Earth*

1973



APRIL 5, 1973 *Pioneer 11 heads to Saturn to take first close-up images of planet and its rings*



DEC. 3, 1973 *Pioneer 10 flies over Jupiter's cloud tops*

1975

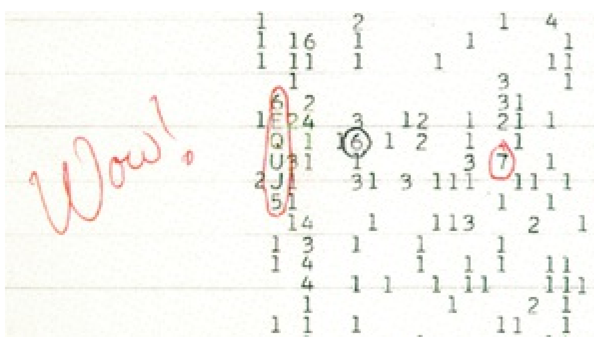
JULY 17, 1975 *U.S. and U.S.S.R. spacecraft dock; crews work together for two days*

1976

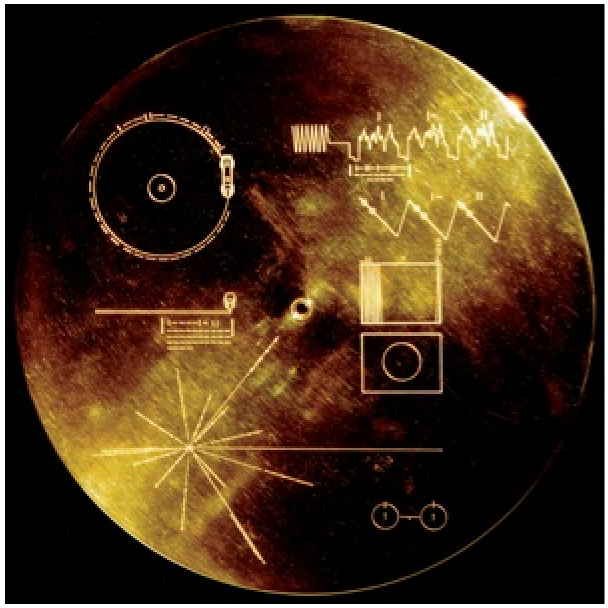
JULY 20, 1976 *Viking 1 lands on Mars; Viking 2 arrives 45 days later*

AUGUST 1976 *Viking 1 probe detects signs of metabolic activity in Martian soil; they are later discredited*

1977

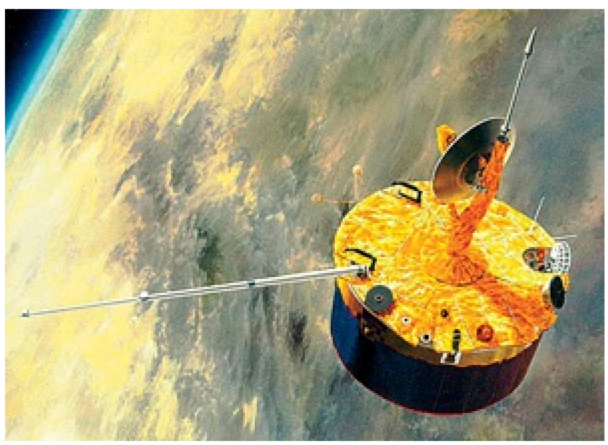


AUG. 15, 1977 *The Big Ear telescope picks up "Wow!" ET signal; later, its authenticity is doubted*



1977 *Voyager 1 and Voyager 2 probes carry gold-plated records with images and sounds of Earth*

1978



MAY 20, 1978 *Pioneer Venus orbiter launched to study planet's atmosphere and map its surface; Pioneer Venus Multiprobe follows on Aug. 8*

1979

1979 *Beginning of Project SERENDIP (Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations)*

1981

APRIL 12, 1981 *Columbia embarks on U.S. space shuttle's first mission*

1983

JUNE 18, 1983 *Sally Ride is first U.S. woman in space*

1984

DEC. 15 & 21, 1984 *Soviet Vega missions set out for Venus; in March 1986 they are redirected to fly by Halley's Comet*

1985

1985 *Project META (Mega-Channel Extraterrestrial Assay) begins, backed by Steven Spielberg*

1986

JAN. 28, 1986 *Challenger explodes; seven-person crew is lost*

FEB. 20, 1986 *Soviet space station Mir launched; it will be occupied for most of the next 13 years*

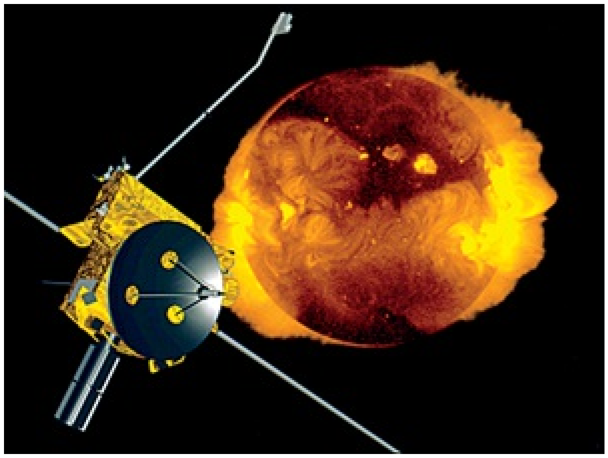
1989

MAY 4, 1989 *Magellan spacecraft launches on mission to map Venus*

OCT. 18, 1989 *Galileo probe launches from space shuttle Atlantis, heads to Jupiter and its moons*

1990

APRIL 24, 1990 *Hubble Space Telescope deploys on mission to reveal the cosmos*

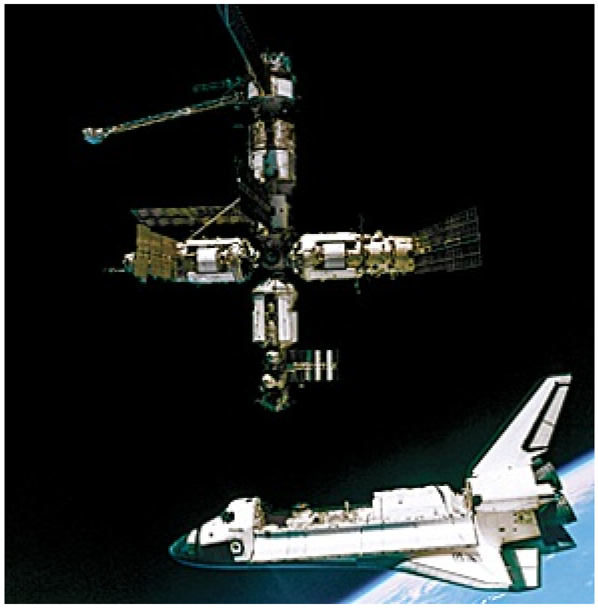


OCT. 6, 1990 *Discovery launches solar probe Ulysses*

1994

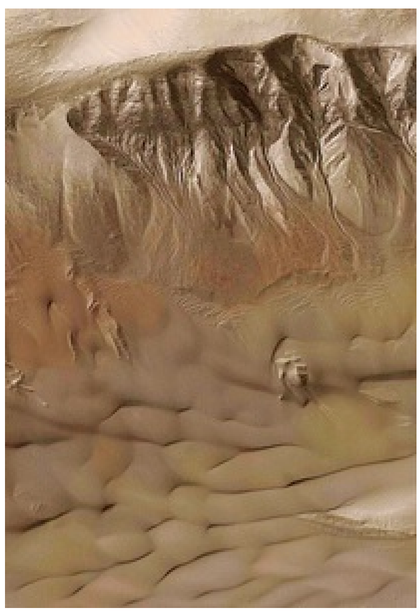
JAN. 8, 1994 *Russian Valeri Polyakov begins record 438 days in space*

1995



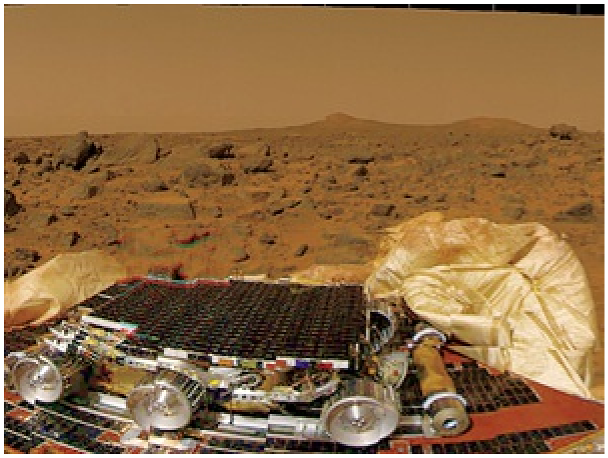
1995 *Project BETA (Billion-Channel Extraterrestrial Assay) begins observations*
JUNE 29, 1995 *Atlantis docks with space station Mir*

1996



NOV. 7, 1996 *Mars Global Surveyor begins journey; will orbit the planet for nine years and find signs of water*

1997



JULY 4, 1997 *Pathfinder lands on Mars; its rover, Sojourner, will explore planet for three months*

1998

DEC. 4, 1998 *U.S. and Russia begin joint construction of International Space Station*

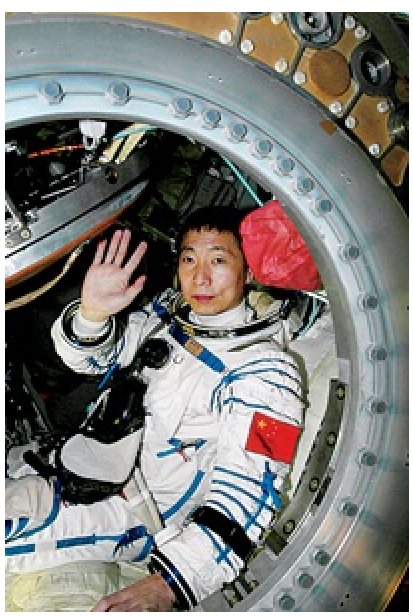
1999

APRIL 15, 1999 *Launch of Landsat 7, most sophisticated of the satellites in ongoing Earth remote-sensing program begun in 1960s*

2001

AUG. 8, 2001 *Genesis probe launched to capture particles of solar wind*

2003

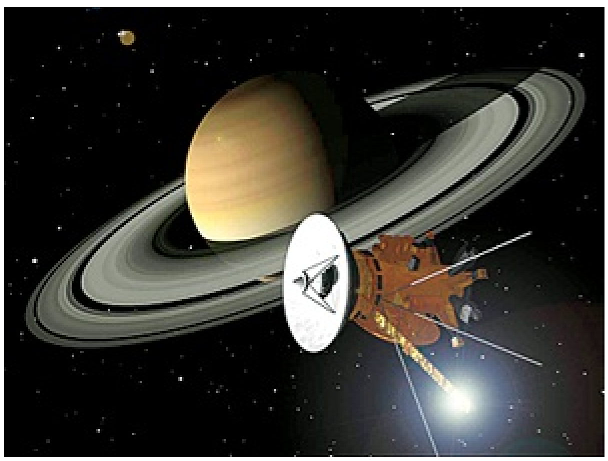


FEB. 1, 2003 *Space shuttle Columbia breaks up during reentry, killing crew of seven*

OCT. 15, 2003 *China sends its first astronaut, Yang Liwei, into space*

2004

2004 *Infrared image of the Whirlpool Galaxy taken by Spitzer Space Telescope*



JANUARY 2004 *Rovers Spirit and Opportunity land on Mars for long-term research and exploration*

JUNE 30, 2004 *Cassini spacecraft begins its exploration of Saturn's rings and moons*

AUG. 3, 2004 *Messenger spacecraft, first probe to orbit Mercury, is launched*
DEC. 25, 2004 *Cassini releases Huygens probe, which lands on Saturn's moon Titan*

2005

JULY 4, 2005 *Deep Impact probe is crashed into a comet to study its composition*

2007

2007 *China, India, Russia and the European Space Agency plan lunar missions*

2008

MAY 25, 2008 *Phoenix probe lands on Mars to search for water*

2009

MARCH 6, 2009 *Kepler Space Telescope begins to look for Earth-like worlds*

2012

MAY 22, 2012 *SpaceX is first private company to deliver cargo to the International Space Station*

2013

DEC. 12, 2013 *Hubble data indicate water vapor plumes from Jupiter's icy moon Europa*

2014

OCT. 31, 2014 *Virgin Galactic's SpaceShipTwo crashes during test flight, killing a pilot*

NOV. 12, 2014 *Soft landing of robotic probe, Philae lander, on surface of comet 67P*

DEC. 14, 2014 *Curiosity rover detects organic molecules in Martian soil, as well as methane vapor*

Life As We Don't Know It

Why stop the search for extraterrestrial life with mere ETs? Maybe there's a "shadow life" —a form of biology we haven't found because we don't even know what we're looking for, a life beyond our comprehension

BY JEFFREY KLUGER

EXTRATERRESTRIAL LIFE MAY or may not exist, but if it does, give it credit for keeping itself under wraps. Long before the first telescope was built, humans began to look for even the faintest rustling in the cosmic leaves that would indicate something is out there. But if the aliens have eluded us so far, it hasn't in any way kept us from thinking we have a pretty good idea of what they'd look like if we found them.

They'd be bipedal and four-limbed like us, of course, though the limbs would be long and gangly, and the fingers—three of them and a thumb—would be slender and bony. They may or may not have suction cups at the tips.

A benign alien would have a large, bald, bulbous head—the better to house its giant, kindly brain. The evil ones would have ugly and angular heads. As for clothes? The jury is still out on that, though bad guys would probably be sheathed in some kind of armor while the good might just be androgynously naked.

OK, maybe none of that actually stands up to close scientific scrutiny. But it's a basic rule of reasoning that when you're trying to wrap your brain around things you don't understand, you start with things you do. In some ways, astronomers and biologists—the ones you would expect to be most capable of theorizing about extraterrestrial life independent of all the Earth-based biases—are guilty of the same thing.

It is their basic assumption that in a universe with trillions of stars and likely more trillions of planets, the search for life will be most productive if we focus on worlds with characteristics most like ours. Such places might not yield creatures with feathers and fingers exactly, but they'll sure gin up something we'd recognize as living.

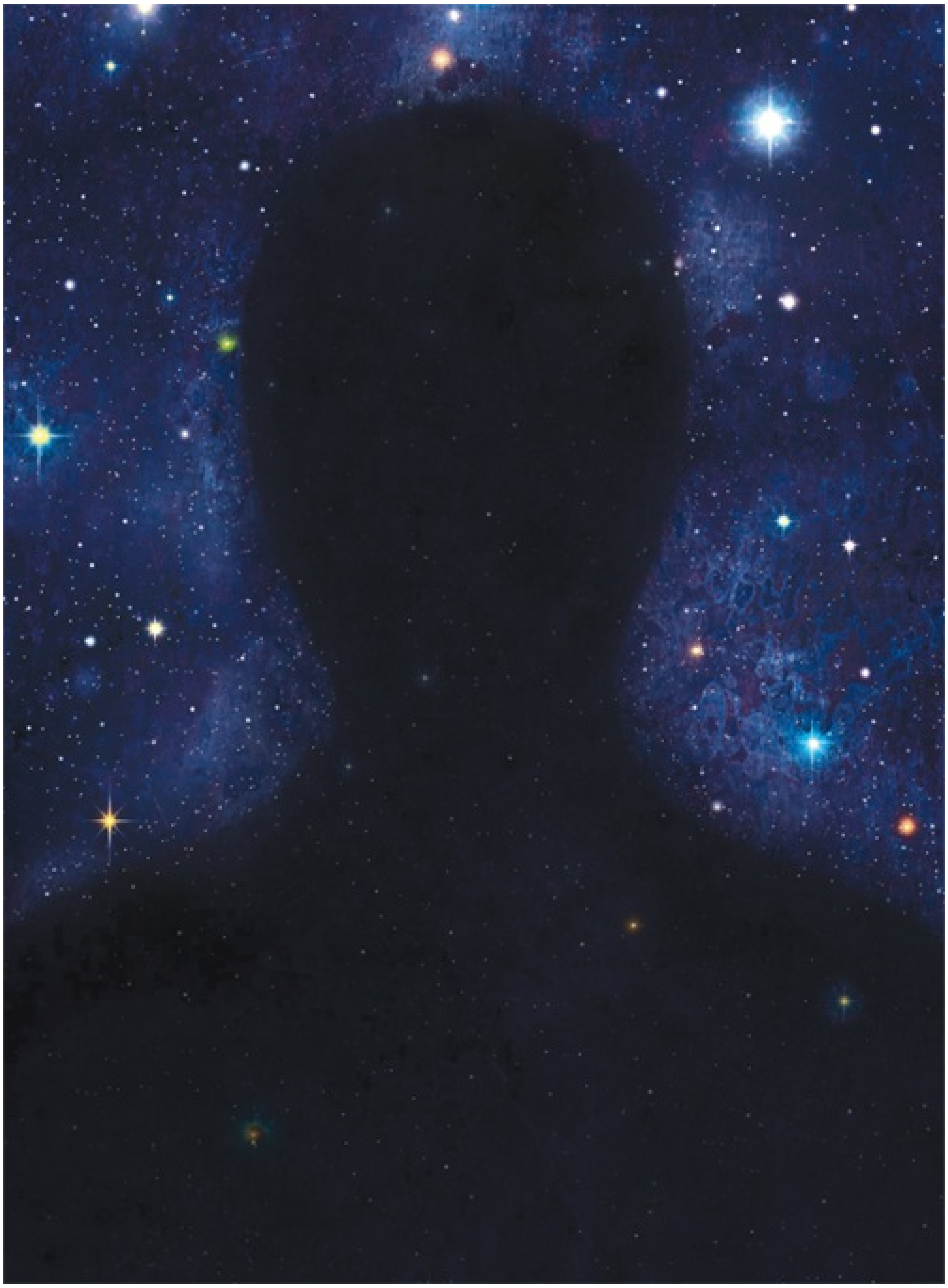
That assumption has determined which planets and moons have drawn the majority of our attention. Mars definitely makes the cut; it was once warm and wet and may still be home to life hunkering down underground. Europa—one of

Jupiter's large moons—is a major player too, with its frozen rind and deep ocean of salty water. We apply similar criteria to the thousands of confirmed and suspected exoplanets we've detected orbiting other suns: gas giants orbiting in hot zones interest us a lot less than smaller, rocky, Earth-like worlds orbiting in the so-called Goldilocks zone, where conditions are not too hot, not too cold, but just right for liquid water to exist.

But life may be—indeed, should be—far more nimble than that. It's vain in the extreme to assume that the entire universe is limited to the same biological cookbook we use. We Earthlings are surrounded by carbon and water and methane, so we use carbon and water and methane. But why not cobalt and antimony, or argon and xenon? What's to prevent elements all over the periodic table from whipping up life-sustaining molecules we can't even contemplate?

"We say that these chemicals don't exist in nature, but that's our nature," says astronomer Dimitar Sasselov, the director of Harvard University's Origins of Life Initiative. "If the chemistry is different because the planet is different, would we even know how to look for life there?"

That, increasingly, is the question scientists are asking. And it's a question that might reframe our entire view of the universe, from a place in which a single kind of life is imprisoned on a single small planet to a thriving menagerie that teems with living things beyond our imaginings.



Southpaw Proteins

We may have to peer millions of light-years into space to discover alternative forms of life, but there is no need to travel much farther than Sasselov's Harvard lab to get a sense of how those forms might operate, at least down at the molecular level. Life as we know it is built on a pillar of proteins, versatile macromolecules that catalyze cellular metabolism, move organic molecules from place to place and both make up and regulate the tissues and organs of the body. Without proteins, there's

nothing. But not any protein will do.

Earthly organisms use proteins that are built from what are known as left-handed amino acids, asymmetrical molecules that jut to one side the way the thumb on your left hand does when you hold it palm up. Right-handed versions of the molecules exist too, but they're much less common and generally useless in biology, so they're tossed aside like a bad brick.

Those bricks, though, actually aren't so bad—nor, it turns out, so rare. When amino acids are manufactured in the lab, they show no handedness at all, turning up as left and right in equal numbers. The problem is, the two varieties don't play well together. Try to combine them to build the polymers that make up cells, tissues and organs, and the process is very slow, if it works at all. But group the left with the left and the right with the right, and the polymers roll right out.

Why only left-handed protein molecules get the job done on Earth is not clear, but one reason may be water. Meteorites that come from carbon-rich comets often contain amino acid molecules, but the type of molecule can change from meteorite to meteorite. "When you analyze molecules that formed in the presence of water," says Sasselov, "they tend to have 10% to 20% more left-handed molecules than right." If right-handed molecules go soggy when they're wet while left-handed ones do fine, it's obvious which would have the edge on a water world like Earth.

The sun may also share some of the credit. Every species of star has its own particular ultraviolet (UV) fingerprint, the emanations from a yellow dwarf like ours differing significantly from the ones produced by a red giant or a brown dwarf. The particular UV energy that bathes a young planet plays a key role in determining the kinds of chemical bonds that get made and the molecules that are formed by them. In the case of Earth, that might have meant a modest initial advantage for left-handed amino acids—an advantage that snowballed over time. "You create a small asymmetry at the start, and everything changes," Sasselov says.

SOMETHING SIMILAR MIGHT be true of the molecules that are virtually synonymous with life: DNA and RNA. Current wisdom holds that on Earth, RNA—or ribonucleic acid—was the first of the pair to emerge, because it was the more versatile molecule, capable of both storing a cell's genetic information and transmitting it to the ribosome, where proteins are made. (The more stable DNA came later; spared the work of running messages to the ribosome, it instead became a sort of cellular disk drive to which information is permanently burned.)

Maybe, though, it is only here on Earth that RNA got the genetic ball rolling.

There's a whole alphabet soup of other possible nucleic acids—including TNA, ANA and FANA (thio-, arabino- and fluoro-arabino acids)—and they could potentially have served the same purpose elsewhere, depending on the conditions present wherever they may have emerged. Sasselov's lab is synthesizing those molecules to see if they are capable of shouldering RNA's early earthly workload.

"So far, RNA works better than anything else," says Jack Szostak, a professor of chemistry at Harvard who is heading up this particular research. "But we still have a lot of work to do."

Sasselov sees no reason at least some other molecules could not turn out to be every bit RNA's equal. "Why was RNA used here?" he asks. "Because the conditions were right for it here."

Once different conditions are established, though, life could spiral out in all manner of corkscrew ways, relying on all manner of unlikely ingredients. Arsenic, for instance, is a powerful poison, but chemically it just misses being an important part of a healthy diet. Atomically similar to phosphorus—which contributes to multiple biological functions, including heartbeat, muscle contraction and nerve signaling—it easily fools the body into absorbing it, usually with disastrous results. On a planet more arsenic-rich than Earth, though, life might adapt to use the chemical safely, with phosphorus becoming the deadly poison.

DO MICROBES we know hint at life beyond our imagination?

E.T. Actually Is Home

For Paul Davies, a theoretical physicist at Arizona State University and the author of 27 books, even this seemingly at-the-edges biology is a bit too familiar. In his mind, the search shouldn't stop with mere extraterrestrial life; it should continue on to what he calls shadow life—or, more prosaically, weird life—a form of biology

we haven't found because we don't even know what we're looking for.

We tune our Mars probes to sniff out signs of methane, for example, because that gas is a byproduct of the biology we know. But suppose a form of life exhales neon or eats krypton or emits a frequency of infrared radiation that reads like background heat unless you know exactly where to look on the electromagnetic spectrum? "We don't know how weird life could look," Davies says. "It's as wide as the imagination. And that's why it's hard to look for." At this point he doesn't sound much different from Sasselov. But then ...

What if shadow life, Davies asks, doesn't just exist on other worlds? What if it lives all around us, on Earth, without our knowing it? The conditions on our planet have changed repeatedly and drastically in the 4.5 billion years it has been around. Each upheaval wiped out most life on the planet, but maybe a few stray survivors retreated to safe, familiar niches in which they could hang on as best they could while all over the rest of the planet, amid entirely new conditions, life got a do-over, an entirely new biology.

"Life as we know it appears to have a single common ancestor," Davies says. "But could life have started many times? And might some of those life forms exist on Earth today in extreme environments and remain undetected?" To find out, he advocates what would be, in effect, an expedition to our own planet. First, we need to imagine all of the different mechanisms by which life could play out, and then we need to look for it in the exotic places it could be hiding. Then again, it could be hiding in mundane or remarkably close-at-hand places too. Since the vast majority of life-forms are microbes, Davies argues that not only could shadow life be lurking under our noses; it could, quite literally, be *in* our noses.

Astronomers like Sasselov, of course, prefer to go hunting for life in places decidedly more distant than the human nose. In some respects, the pursuit should not be any more difficult than the ones we are already engaged in. We can simply recalibrate the telescopes and space probes we use to uncover clues to the kinds of life we understand to look for the fanciful, fever-dream kinds we've never even considered.

Meanwhile, if such life exists, it may just as easily be turning its own instruments and signals our way, even as it tries to imagine how anything could survive on a tiny planet sloshing with water, smothered in oxygen and forced to rely on so deadly an element as carbon. But should its exploration be guided by imaginative scientists—the kind, as it happens, we have here—it too might decide that long-shot worlds

are worth a look.

Aliens Among Us

The stuff of biology exists throughout the universe. Sometimes it hitches a ride on meteors, and it could be seeding life everywhere

BY JEFFREY KLUGER

AN ASTEROID headed for Earth, such as this one, might just contain some spark of life, in the form of amino acids, nucleobases, sugars or other organic matter.

THE FIREBALL BEARING DOWN ON THE LITTLE town of Tata, in southwestern Morocco, in July 2011 was like nothing the locals had ever seen. There was one sonic boom, then another, as a yellow slash of fire cut across the sky. The yellow turned to a landscape-illuminating green, the fireball split in two, and a hail of smoldering rocks crashed to the ground across the surrounding valley. With that, our planet's latest invasion from Mars was over.

Scientists quickly pounced on the incoming ordnance, dubbed the Tissint meteorite after the type of rock from which it was formed. They wanted to know its chemistry and mineralogy—which proved it came from Mars—and they wanted to know one more important thing: whether it was carrying passengers. It's a question space scientists havebegun asking a lot.

Life, as far as we can prove, exists only on Earth. There is our modest planet circling our modest star, and then there is the unimaginable hugeness beyond. But in that whole great cosmic sweep, we're the only little koi pond in which anything

is stirring. As far as we can tell, at least.

YET THE COSMOS is awash in the stuff of biology. Water molecules drift everywhere in interstellar space. Hydrogen, carbon, methane, amino acids—the entire organic-chemistry set—swirl through star systems and are taken up by planets and moons. In 2009, NASA's Stardust mission found the amino acid glycine in comet Wild 2. In 2003, radio telescopes spotted glycine in regions of star formation within the Milky Way. And meteors that landed on Earth have been found to contain amino acids, nucleobases (which help form DNA and RNA) and even sugars.

That raises a tantalizing question: If the building blocks of life can rain down anywhere, why not life itself—at least in the form of bacteria? Such an improbable idea, known as panspermia, has been chattered about by scientists since the 19th century. But back then, there wasn't much knowledge of what the cosmic ingredients of life were or how to detect them even if they could be identified.

That's all changed. A welter of new studies in the past few years have shed light on the panspermia idea—and in the process have changed our very sense of our place in the cosmos. Never mind that stale image of life on Earth existing in a sort of terrestrial bell jar, sealed off from the rest of the universe. Our planet—indeed all planets—may be more like a great meadow, open to whatever spores or seedlings blow by.

"I think there's definitely a role meteorites have to play in at least getting prebiological materials to planets," says Chris Herd, a meteorite expert at the University of Alberta, who has studied the Tissint rocks. "A lot has to go right for an actual microorganism to go from planet to planet. But in some cases, they just might survive the trip." If they made that trip to our ancient Earth, we may not merely have encountered aliens; we may be the aliens.

The search for life in rocks from space has met some bumps along the way. On Aug. 6, 1996, NASA stunned the world by announcing that a meteorite from Mars, prosaically known as ALH84001, contained evidence of what appeared to be fossilized bacteria.

LIFE ON MARS, the headlines screamed, and that was exactly the conclusion the researchers had tentatively reached. "It's an unbelievable day," said then NASA administrator Daniel Goldin. "It took my breath away."

Breathtaking, yes. If only it weren't a false alarm. Further study of 84001 failed to rule out inorganic processes for the seemingly biological clues it contained, and

while the rock continues to spark debate, no one disputes that the evidence was not the slam dunk it originally seemed to be.

In the years since, similar research has proceeded apace, even if the press releases have been decidedly more measured, and the case for panspermia is being convincingly rebuilt. In 2012, Herd and his colleagues published a paper in the journal Science showing not just how biological material could get to Earth but also how it could survive a long trip in space.

The study focused on what's known as the Tagish meteorite, for the frozen lake in British Columbia on which it smashed itself to fragments on Jan. 18, 2000. Within days of the impact, scientists collected the debris—making no direct hand contact with it in order to minimize biological contamination—and quickly transported it to cold storage. When Herd and his colleagues got hold of four of the fragments and cracked them open, they found that the debris very much warranted such caretaking.

TAGISH, THE METEORITE named after the frozen lake in British Columbia on which it landed, was found to be rich in intriguing organic molecules.

Distributed throughout the rock were more than just the organics that had been seen before; there were also others in different stages of sophistication, simpler molecules giving way to complex ones and more complex ones still—a bit like finding caterpillars, cocoons and butterflies all in the same little nest. The rock, it seemed, had been acting as a sort of free-floating incubator, with traces of water trapped in its matrix combining with heat from radioactive elements to keep things warm and effectively pulsing.

"These asteroids form in space, you dump in organic molecules, a little water ice and a little heat, and then they just start to stew," says Herd. That slow cooking went on for millions of years in the Tagish rocks until the supplies of heat and water were exhausted and the process shut down.

TEXUS 49, a sounding rocket, launches from the Esrange Space Center in Kiruna, Sweden.

Scientists salvage DNA molecules from the outer payload of a TEXUS rocket.

This doesn't necessarily mean that similar rocks landing on Earth billions of years ago were the start of all terrestrial life—or even that they contributed to biological processes already under way. Yet the organics in the Tagish meteorite have a curiously familiar feature. Amino acids come in one of two varieties: left-handed and right-handed, defined by an asymmetrical structure that points either one way or the other. All earthly life uses the left-handed kind—a puzzling fact given that right-handed amino acids should work just as well—and the Tagish amino acids are left-handed too. How did that southpaw bias get started on Earth? Herd's findings suggest that the influence could have come from beyond.

It's easy enough to imagine how a meteor that accreted in space and then spent its life flying through the vastness could eventually find its way into the gravity field of a planet if it came too close. Harder to figure is what it takes to get biologically contaminated material from the surface of one planet to another. Something, after all, has to launch the stuff in the first place. Typically that something is a meteor strike, which hurls debris into space, where it slowly drifts from one world to the next. Earth and Mars have exchanged material this way for billions of years, though more in the early days of the solar system, when the cosmic bombardment was

greater.

The kind of life that can get started on the warm, wet surface of a planet, contaminate its rocks and hitch a ride to the world next door is a lot more complex than the mere prebiology that can get cooked up in space. The problem is, most of those organisms—probably the single-celled kind like those the ALH84001 scientists thought they had found—can't live through the shock heating that occurs when debris is blasted into space. Ones nestled deep within rock, though, might.

IN 2014, CORA THIEL, A professor of anatomy at the University of Zurich, showed that even some surface biology at least could have a shot. She and her colleagues painted areas of a sounding rocket with a solution mixed with DNA that coded for antibiotic resistance and fluorescence. The rocket was launched from Sweden to a suborbital altitude of 168 miles and remained aloft for 13 minutes, with heat from atmospheric friction peaking at more than 1,800°F. After the rocket's return, at least some of the solution on its skin was found to have survived—including 53% of it that was embedded in screwheads. And when all of that DNA was cultured in the lab, 35% of it proved viable.

Remaining alive for the hundreds of thousands or millions of years it would take to travel from world to world would be another matter entirely for organisms, but it should not be impossible. Earthly bacteria that live in extreme environments go dormant or even freeze-dry until conditions improve and they stir to life again.

In June 2012, investigators from the University of Colorado–Boulder studied bacteria found in the Atacama region of South America, where rain almost never falls and temperatures go from 13° at night to 133° the next day. Microbes nonetheless thrive there, sucking energy from traces of carbon monoxide in the air and extracting moisture from exceedingly rare snowfalls. The rest of the time they hibernate. There's no apparent reason an adaptation that nifty should be confined to Earthly life.

Whatever biology is flitting about out there would not even have to be limited to traveling from planet to planet; it could also hop from one star system to another. Such a scenario was long considered scientific fantasy. Not only would the transit times between planetary systems be prohibitively long for even the hardiest bacteria—on the order of 1.5 billion years—but the speed a space rock needs to travel to escape the gravity of its home stellar system should be too great to allow the rock to be captured by another. In September 2012, however, a team of

researchers from Princeton University, the University of Arizona and the Centro de Astrobiología in Spain figured out a neat solution that sidestepped these problems.

Most panspermia models assumed that the only way a rock could escape a stellar system was if it passed close to a large body like Jupiter and was gravitationally ejected at a speed of about 18,000 mph. But the investigators used a computer to model a slow-boat escape, known as weak transfer, in which a rock gradually drifts out through a planetary system until it is so far from its parent sun that the slightest flutter in its trajectory could tip it into interstellar space. “At this point,” says Princeton astrophysicist Edward Belbruno, one of the co-authors, “mere randomness determines whether it gets out or not.”

And don’t worry about those extreme distances to other stars in the neighborhood. About 4.5 billion years ago, the infant sun was part of a tight grouping of nascent stars known as the local cluster. The herd dispersed after less than 300 million years, but a weak-transfer rock that escaped within that window could have reached the next star in about a million years. “Trillions of rocks could escape,” says Belbruno. “Over the course of 300 million years, about 3 billion might have struck Earth.”

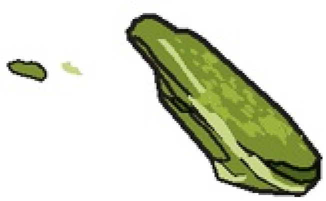
It’s impossible to know if even one of those 3 billion would have harbored biological material, especially so early in the history of the local stars. But if the new studies say anything, it’s that it’s equally impossible to continue to see the Earth and its organisms as somehow separate from the rest of the cosmos. The universe, it seems, does not just produce the basic materials for biology; it is steeped in them.

Precious Cargo

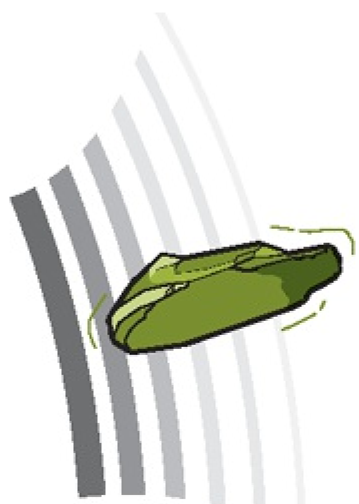
New computer simulations show how prebiotic material or microbial life could have originated in a distant solar system, then hitched a ride to Earth.

1 Meteor collisions expel rock containing organic material from a planet's surface

2 After escaping the planet's gravitational pull, the rock drifts through its solar system

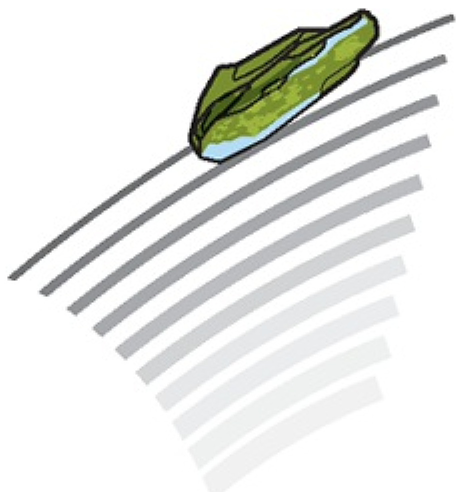


3 Once at the edge of the solar system, the rock requires only a flutter in its trajectory to enter deep space



4 Trace water and radioactive heat within the rock incubate its cargo during the long journey

5 The star cluster in which our sun was born was once tightly grouped, reducing the rock's transit time as it is pulled into our solar system



6 The rock and its cargo, attracted by Earth's gravity, plummet through the atmosphere. If the organic material survives the plunge, it finds a very hospitable new home

Extremophiles

There is virtually no corner of Earth so inhospitable—so cold or hot, deep or desolate—that scientists cannot find some form of biology that calls it home. If creatures can adapt to make it there, maybe they can make it anywhere. Even outer space

BY JEFFREY KLUGER

TULLIS ONSTOTT, a professor of geosciences at Princeton, studies life deep under the Earth's surface, including the hell worm, below, Which he discovered in a South African gold mine.


MONO LAKE in California has tufa, calcium-carbonate spires formed by freshwater springs and alkaline lake water. Brine shrimp(below) thrive there.


Brine shrimp

THINK YOU'RE TOUGH? YOU'RE not so tough—and there's a very good reason for that: you're human. For all the airs we like to put on about our sublime adaptive fitness, we're as delicate as orchids.

We need water—lots and lots of water. Indeed, the human body is 65% water. We freeze or cook to death if we venture for too long outside a narrow range of 40° to 100°F—barely a flicker of the thermometer in a solar system in which temperatures range from –400° at the moon's south pole to 25 million degrees inside the sun. We swoon from lack of oxygen if we so much as climb too tall a mountain and require just the right acidity-alkalinity balance—pH 6.5 to 7.5—to stay alive. As for our ability to withstand radiation? Please. We don't submit to even a dental x-ray without a heavy lead apron protecting our vitals.

Yet with all that, we still fancy ourselves the biological gold standard. Could life exist on Venus? Nah, too hot. Saturn's moon Titan? Too cold. Nearly all of the other worlds we've discovered throughout the galaxy we have similarly dismissed as too dry, too salty, too dark, too toxic. Until you discover a garden world like Earth,

don't call us; biology doesn't have a chance.

Except much of Earth itself is nothing like a garden, and biology, it turns out, is doing just fine all over. Organisms thrive under the dry, blistering sands of Chile's Atacama Desert; in the frigid permafrost that covers Antarctica; in the boiling, 750° heat of hydrothermal vents at the bottom of the oceans; in the acidic hot springs of Yellowstone Park. There is barely a place scientists have turned a shovel, dipped a ladle or placed a drill bit that they haven't found some forms of biology making their happy living. While the organisms may all belong to different taxa, or families, they are all part of a larger group known less formally as extremophiles—life-forms that go where other species dare not tread.

The very definition of adaptation is the ability of an organism to play the environmental hand it's dealt. And if life is playing those tough hands so well on Earth, there's no reason to think it couldn't be doing the same right now on other worlds too.

Worms from Hell

THE CAVE OF THE LIGHTED HOUSE in Tabasco, Mexico, is home to snottites, mats of single-celled extremophilic bacteria that hang from the walls and ceilings and get their energy from sulfur instead of sunlight.

Tullis Onstott knows better than most the strange places some creatures call home. The Princeton geologist got his first glimpse of one such hard-luck habitat in 1996, when he ventured a mile belowground into a South African gold mine to study the geology—and potential biology—of an environment that has been effectively isolated from the world above for millions of years. The rock samples he collected were so radioactive they had to be sealed in a metal canister in order to be transferred safely to the lab, but when Onstott got them there and cracked them open, he found colonies of bacteria doing what bacteria do, which is to say efficiently eating, excreting and, of course, reproducing. The infinitesimal trace of

water that had seeped from above was more than enough to keep the organisms hydrated, the iron and other metals in the rocks served as a ready form of food, and as for that radiation? Well, what better way to split hydrogen atoms away from water molecules so they could serve as the final piece of the bacteria's diet? "Hydrogen gas is like junk food to a lot of bacteria," Onstott told a Princeton publication shortly after the discovery.

Bacteria, however, are easy—or at least easier than multicellular organisms, which have an infinitely more complicated body plan that includes an infinitely more complex array of internal systems. In other words, they have more moving parts that can break down if the environment gets too harsh.

But bigger critters turn out to have their own kind of adaptive nimbleness. In 2011, Onstott went deeper into the mines—two miles down this time—and drilled holes into the walls to look for more forms of hermit life. As he was extracting the drill, he noticed flecks and filaments clinging to the bit that looked decidedly organic. On closer examination, they turned out to be nematodes—roundworms—similar to ones that have been found in other extreme environments, like hot springs.

Onstott gave the organisms the name *Halicephalobus mephisto*, worms from hell, which does a pretty good job of describing both what they are and where they live. "The discovery of multicellular life deep in the surface of the Earth," Onstott and his team wrote, "has important implications for the search for subsurface life on other planets."

Up into the Light

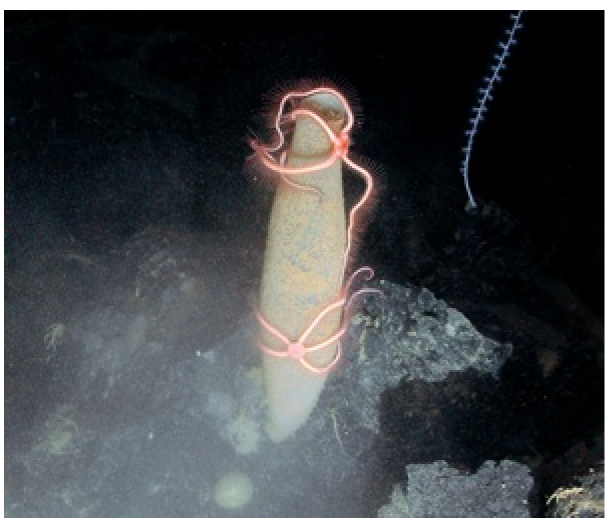
THE CHERNOBYL CONTROL ROOM in reactor 4, where a species of black fungus grows that is impervious to, and even dependent on, radioactivity 500 times as high as normal following the 1986 meltdown

Belowground isn't the only place life has it hard; indeed few places on Earth would

seem less hospitable than California's otherwise picturesque Mono Lake. Known as a terminal lake because water flows in but doesn't circulate back out, it lives up —or down—to that dark label. As old water evaporates and new water replaces it, the lake's concentration of chemicals grows greater and greater. This has left it exceedingly salty and alkaline and largely anaerobic, or free of oxygen. Yet Mono swarms with an array of adaptive creatures all the same: salt-loving brine shrimp that hatch in the trillions each season, flies that have mastered breathing underwater by carrying air bubbles with them, spirochete bacteria that need no oxygen and gorge on sulfur.

Antarctica's Lake Untersee is a different kind of nasty, with heavy concentrations of methane and an alkalinity similar to that of laundry detergent. Yet its floor is covered with large conical structures known as stromatolites, which are built of layer upon layer of various types of cyanobacteria (blue-green algae) and other microbes.

Life on Earth adapts even to conditions that were created not by the Earth itself but by the serial messes human beings make of it. The waters of Rio Tinto in Spain and Iron Mountain in California run so thick with the heavy metals left behind by local mining operations that almost no organisms can live there. That's bad news for the native species that once called the rivers home but good news for the bacteria that moved in to take their place, protecting themselves from industrial toxins with a biofilm membrane through which they also absorb nutrients.



SPONGES AND BRITTLE STARS grow on the ocean floor near a volcanic vent, which provides life-sustaining minerals to the organisms.

THE ATACAMA SALT FLATS, high in the Chilean Andes, one of the most extreme habitats on Earth, contain algae that need very little water.

Spain's acidic and iron-rich, hence reddish, Rio Tinto is home to anaerobic bacteria.

EVEN WHAT IS ARGUABLY THE most lethally polluted place on Earth, the abandoned Chernobyl power plant in the former Soviet Union, has become home to new, highly adaptive residents. Nearly three decades after the meltdown that wrecked the reactor and turned the surrounding city of Pripyat into a ghost town, a 12-square-mile exclusion zone remains in place—a no-go region for anyone, or anything, not properly suited. Yet on the walls of the reactor itself a species of black fungus is growing, impervious to, and even dependent on, a level of radioactivity 500 times as great as the normal background level. Rich in the pigment melanin,

the fungus apparently uses ionizing radiation to fuel its metabolism in the same way plants use chlorophyll to convert sunlight into energy.

Now, nobody pretends that the existence of extremophiles on Earth is proof of similarly rugged species living in similarly punishing environments on other faraway worlds. But it does boost the odds. If the frigid waters of Untersee Lake can be home to bacteria, why can't the frigid ocean beneath the ice shell that covers Jupiter's moon Europa? If Untersee organisms can thrive on the lake's methane, why couldn't other life-forms do the same in the gaseous seas on Saturn's Titan? If a fungus can grow on the walls of the still-hot tomb that is Chernobyl, why not on the planets PSR B1257+12 b, c and d, all of which, in orbiting a pulsar nearly 1,000 light-years from Earth, are seared by intense radiation every 6.22 seconds as their parent star spins? By such standards, the prospect of life on Mars—perhaps the world that fills our imaginings most—is practically a free throw. The planet was once warm and wet, after all; when it became a frozen desert, any life that was already in place could have simply moved underground.

Human beings, to our credit, have always hedged our biological vanity. When we speak of how unlikely it is that life exists on any alien world, we are thinking specifically of "life as we know it." Increasingly, however, we're learning that there is also life as we don't know it, haven't considered it and never even imagined it before. In a universe with a literally uncountable number of worlds, there are almost assuredly uncountable routes biology has taken too. We may not be able to go out and look for it yet, but we can surely broaden our thinking enough to contemplate what it might be like.

What's a Nice Alien Like You Doing in a Place Like This?

Someday we may wake up to find giant starships hovering over our fair metroplexes or E.T. cowering in our toolshed. Then what? We'd like to think we'd be gracious hosts. Don't bet on it

BY JEFFREY KLUGER

UNWELCOMED GUESTS In 1951's *The Day the Earth Stood Still*, intergalactic visitors come to our planet in peace but are not met with kindness.

LET'S BE HONEST: IF WE EVER encounter an extraterrestrial, we'll probably lose our marbles—and not in a good way. We've been contemplating the meeting for a long time, and the stories we've told ourselves about how things will unfold have not been encouraging.

There is H.G. Wells's *War of the Worlds*, in which invading Martians lay waste to much of the Earth until they are defeated by a terrestrial virus. There is ***Independence Day***, the 1996 movie in which invading aliens—who clearly haven't been paying attention—lay waste to much of Earth until they are defeated by a computer virus. There is the celebrated episode of *The Twilight Zone* that involved seemingly kindly aliens who arrive on Earth toting a handbook called *To Serve Man*, which is a perfectly nice beginning—until it turns out the handbook is a cookbook.

Even our more virtuous movie aliens have had an edge of the sinister about them. Take Klaatu, the wise extraterrestrial in 1951's *The Day the Earth Stood Still*, who lands in Washington to deliver the message that our planet is on a sort of galactic probation list and will be wiped out if we don't quit playing with atomic weapons. Try peace—or else.

In fairness to us, we do seem to have moved a bit beyond our afraid-of-the-dark ways of late. We sent the Voyager 1 and 2 spacecraft aloft in 1977 carrying golden disks encoded with information explicitly designed to introduce ourselves to aliens and even tell them where we live. Lots of us, professional astronomers and volunteers alike, continue to scan the skies for signals that might suggest an alien intelligence. And the one time we thought we had uncovered solid evidence of extraterrestrial biology, the reaction was far more celebratory than scared.

On Aug. 7, 1996, NASA announced that a meteorite from Mars contained what appeared to be fossilized microbes. The mood at the mid-day press conference that broke the news was one part sober and two parts flat-out giddy. President Clinton, who was in the midst of running for re-election, was only too happy to have the opportunity to perform the greatest galactic touchdown dance since President Nixon phoned the Apollo 11 astronauts on the surface of the moon.

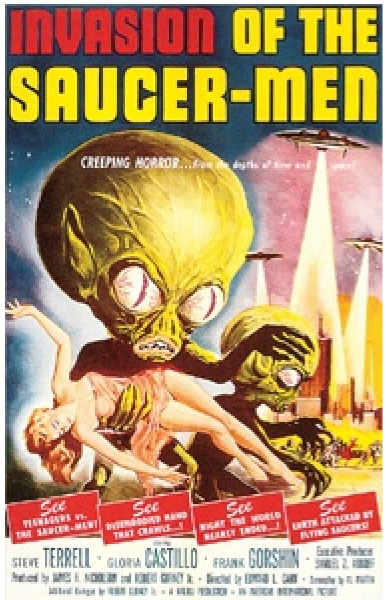
"If this discovery is confirmed," he said at a Rose Garden press conference, "it will surely be one of the most stunning insights into our universe that science has ever uncovered . . . We will continue to listen closely to what it has to say as we continue the search for answers and for knowledge that is as old as humanity itself but essential to our people's future."

Despite these examples of good behavior, though, let's not get too full of ourselves. Even at the time, the Mars meteorite was thought to contain nothing but a single microbe—a long-dead one, at that—and most subsequent analyses

concluded that, in fact, the object in the rock was not biological at all but, rather, geological in origin. All those eager stargazers have their ears primed for nothing more than rhythmic beeps from millions of light-years away—and have so far come up empty. The most enthusiastic Mars partisans don't expect NASA's rovers to uncover complex life—much less life that is both complex and intelligent.

Still, the original question is an instructive one: How will we react if we ever hit cosmic paydirt? Suppose one of our spacecraft or radio antennas did pick up signs of extraterrestrial intelligence. Suppose, more dramatically, E.T. actually landed here. What then? The odds are, alas, depressingly short that what would happen next wouldn't be pretty.

HUMAN BEINGS ARE, FOR BETTER and often much worse, a tribal species. Give us a way to define and divide ourselves—color, language, religion, geography, culture, gender, team affiliation, and certainly planet if it ever comes to that—and we zealously seize on it. Such a worldview once paid survival dividends, and in some ways it still does. Members of your family or clan or community are the people most likely to protect and look out for you. Those guys living two valleys away are likelier to see you as a competitor for resources and mates, and given a chance will deal with you accordingly. So we love the family and hate the stranger, and that behavioral coding, once laid down, isn't erased easily.



DAYS OF RECKONING Aliens arrive in, from above, ***Independence Day*** (1996), *The Twilight Zone*'s "To Serve Man" episode (1962) and *Invasion of the Saucer Men* (1957), and none of them have our best interests at heart.

School segregators, ethnic cleansers and people who blow up houses of worship don't think in those terms consciously, but the impulse is at least part of what's behind the us-versus-them atrocities they commit.

Sometimes the savagery is us-versus-us. The early days of the Cold War are remembered as an entirely bipolar era, with the U.S. and the Soviet Union standing astride competing halves of the world as their various client states fell in behind them. But once the intercontinental ballistic missiles got armed and aimed, things began to break down within the friendly camps too (at least in the U.S.). Backyard fallout shelters were cramped affairs—big enough for you and your family and absolutely no one else. It was for that reason that the best-equipped shelters often included a shotgun, the better to repel neighbors who couldn't be bothered to dig their own burrow when they had the chance but, when the bombs started falling, wanted to huddle up in yours.

Conversely, one of the most inspiring scenes in *Independence Day* occurs when all the citizens of the world join forces to repel the aliens and the screen is filled with images of Israeli and Arab militaries, side by side, working together, the dire circumstances turning enemies into brothers. Gorgeous—and quite likely nonsense.

It's hard to imagine even the nominally confederated nations of the European Union pulling together to fight extraterrestrials without France crabbing to

Belgium that Italy needs to pull its own weight, Germany scolding Greece that a military costs money and they should have thought about that before they ran up such huge deficits, and Great Britain trying to figure out if ETs can swim and if maybe, one more time, the Sceptered Isle could just wait out the whole mess on the other side of the Channel. As for factions elsewhere in the world that, even in the best of times, spend most of their energy blowing one another up? Not a chance.

We don't need an alien landing to show us how we'll react to a perceived external threat. We already know the answer is: not well. Consider the hysterical reaction to the Ebola virus alighting on American shores (ground all flights! quarantine all travelers!). Consider the incessant drumbeat about the need to seal the U.S.-Mexican border against whatever menace is lighting up cable news that day, be it swine flu or ISIS or Al Qaeda.

A little less obvious is how proof of extraterrestrial life would affect our religious beliefs. The last half-millennium has been a difficult time for some of the most deeply and fundamentally devout among us. It's easy to imagine how human beings came to have a geocentric view of the universe; all visual evidence tells us the Earth sits at the hub of a great clockwork of nested wheels, with stars, planets, moons and comets passing overhead in long circular journeys. We are easily the most advanced beings on the one world for which that great sky show is playing out. Surely we must be the supreme creation of a Supreme Being.

But then science showed that we're not the center of the universe; we're barely in the distant countryside. We're a lone planet circling one of 300 billion stars in the Milky Way, which itself is one of perhaps 100 billion galaxies in the universe. Our final claim to uniqueness is that for the moment, we remain the only known planet with life. If that changes—when that changes—we'll all have to find our own ways to adjust our sights.

On that score, there is hope. President Clinton may have been just a pol on the campaign trail in 1996, but his Rose Garden comments were a good step in the right direction: open, humble, wisely acknowledging what at that moment seemed like an epochal shift. Voyager's golden records, equal parts olive branch and homing beacon, were baggage that took real courage to pack, because once they were launched, they could never be called back.

Organized religion, too, is beginning to see the future differently. At the Vatican, Jesuit brother Guy Consolmagno, the Pope's astronomer, is promoting a new kind of faith that happily embraces science. The 2014 book he co-authored with a

fellow Jesuit is provocatively titled *Would You Baptize an Extraterrestrial?* His answer is straightforward: "Only if she asks." The response is whimsical and wonderful. And it suggests a profound change.

As a species we have undeniably made progress over time, from the primordial soup to the state of nature to warring tribes to a global community that can, on its good days, feed its kids and heal its sick and make great discoveries without killing too many of its own. Yet we have a long way to go. It will be a very good thing when we at last shake hands with an extraterrestrial. But it may be a better thing still that the big day remains at least a few years away.

So ... What Would an Alien Look Like?

No one knows. But that hasn't stopped scientists in various disciplines from making educated guesses

Our planet, ourselves

To imagine a species, know its living environment. Gravity, atmospheric chemistry, climate—all helped shape life on Earth. And so it would elsewhere. Says Don Lincoln, author of *Alien Universe: Extraterrestrial Life in Our Minds and in the Cosmos*, "On a low-gravity planet, creatures could be more spindly, because they would be able to overcome the pull of gravity." Conversely, high gravity likely means short and squat. A world of water? Think streamlined—hey, it works for fish and whales.

Recipe for success

The life we recognize has specific requirements, says Lincoln. “Evolution strives for energy efficiencies in all body movement.” We also have an idea of what organisms should be made of. “Carbon by far allows for the most complex structures,” Lincoln says. And what will fuel them: some form of respiration, probably oxygen-based. But even here on Earth, anaerobic species survive on something other than oxygen, and organisms elsewhere may be built of very different stuff.

See level

Consider eyes. Virtually every evolved species on Earth has them. Why? Because they confer a clear natural advantage. So doesn’t it make sense that other higher beings would have them too? “I believe complex organisms beyond Earth would in general look like terrestrial life,” says Steven Dick, the astronomer and astrobiology chair at the Library of Congress’s Kluge Center. “Only a limited number of engineering solutions are possible when it comes to the necessities for life.” The idea that aliens would inevitably resemble Earthbound creatures is called convergent evolution, and its point is this: You can’t build UFOs unless you’ve mastered technology, and you can’t master technology if you don’t have sensory organs. Dexterous appendages and an information center too, for that matter.

Lucky breaks

One person’s convergence is another’s happenstance. Some scientists think our traits are unique, specific to Earth alone. Take symmetrical bodies. As Lincoln explains, “Our symmetry comes from an evolutionary accident 500 million years ago, when backbones formed.” Symmetry, then, was an accident that happened to work out well here. But that doesn’t mean life across the universe will be similarly designed. Same goes for number of limbs: We have four because we evolved from a four-limbed ancestor. Somewhere else, though, six or eight or 18 might work just as well, and be much more likely in an alien family tree that sprung from a multi-limbed ancestor.

Minds over matter

Then again, maybe aliens will have no physical presence at all. Maybe E.T. will be AI. Any civilization capable of coming calling would be more advanced than

our own, the argument goes, and that probably translates into some kind of artificial intelligence. “At the point at which you can be found by another society,” says Seth Shostak, director of the Center for SETI Research, “you’re on the verge of building AI.” And with a sci-fi ability to evolve, alien AI would quickly unseat the organic life that created it. It’s been a little more than a century since we developed radio technology, and our own AI moment may be only a matter of decades away. Considering the age of the universe, number of potentially habitable planets, and time it would take to transmit or travel from them, future visitors are as likely to be hyperintelligent machines as little green men. (That’s a pop-culture construct, not a scientific one, by the way.)

Why We Believe

The heyday of ancient astronauts and alien abductions has come and gone. But we can still get carried away by dreams of intergalactic encounters. Does that make us crazy? Not at all.It makes us human

BY DAVID BJERKLIE

ALIENS FROM SPACE USED TO BE A PRETTY FAR-OUT notion. Although they loomed large in our popular culture, sensible folks just didn't take seriously the possibility of real-life spacemen. Until they did. And that's when things got even stranger.

Sure, an original cottage industry of speculation was spawned in the 1960s by Erich von Däniken, whose books argued that not only were aliens real but that they had already visited Earth, lending a hand in building the pyramids while they were at it. Von Däniken's theories created a huge stir among the public at large, selling more than 60 million books, but it wasn't until decades later that aliens (or at least a dispassionate consideration of them) first infiltrated the sober halls of academia. In the summer of 1992, no less high-minded an institution than MIT hosted a small conference on the abduction experience. By 2010, no less a deep thinker than Stephen Hawking was pondering not only who could be out there, but what they could be up to. "I imagine they might exist in massive ships," Hawking theorized, "having used up all the resources from their home planet. Such

advanced aliens would perhaps become nomads, looking to conquer and colonize whatever planets they can reach."

That same year, the 350-year-old Royal Society of London convened a conference called "The Detection of Extra-Terrestrial Life and the Consequences for Science and Society." A couple of Nobel laureates sat in on the two-day affair, which birthed the publication of 17 scholarly papers in a dedicated issue of *Philosophical Transactions of the Royal Society* A. In short, the search for ET has hit the bookish big time.

What on Earth (or, more to the point, anywhere but Earth) happened? In truth, all the attention isn't that much of a leap. We humans have always embraced at least the idea of aliens. When it comes right down to it, we really have no choice.

QUITE A STONE'S THROW Stonehenge, the giant cosmic calendar, could only have been built by intergalactic space visitors, right?

ALIEN'S-EYE VIEW Ancient line drawings, some as wide as three football fields, were made in the dry desert soil of southern Peru. But why? And for whom?


LET THERE BE LIGHT A carving in the Dendera Temple complex has led some to believe that aliens brought electricity—and incandescent bulbs!—to ancient Egypt.


SPACE ODDITY Ancient-astronaut advocates firmly believe this temple carving shows Mayan king Pakal manning the controls of a UFO.

WESTERN PHILOSOPHY HAS long argued that the Self requires the existence of an Other, and aliens are an Other in spades. As Caleb Scharf, the director of astrobiology at Columbia University, says, “They speak to deep existential questions.” In the possibility of intelligent alien life we see a reflection of our innermost thoughts, hopes and fears. Wanting to look into the face of an alien, says Scharf, “is like wanting to have a mirror to look into, a mirror we can compare ourselves to.”

But our inclination to believe in aliens isn’t a single—or necessarily simple—impulse. For some people, ETs provide explanations for what we don’t understand about our own human history. Exhibit A is the series of ancient landscape figures called the Nazca Lines in southern Peru. These figures, or geoglyphs, are shallow but enormous line drawings in the desert soil, depicting birds, spiders, monkeys, lizards and other animals. They are so large—some are two or three football fields across—that they are best discerned from a hovering aircraft. Thus, the reasoning goes, they must have been made by or for the inhabitants of flying saucers. Such

fantastical visitations also "solve" Stonehenge, Mayan temple carvings that allegedly depict King Pakal sitting at the controls of a spaceship, and a symbol found in Egypt's Dendera Temple complex that resembles a modern lightbulb, complete with a squiggly filament inside and a plug at the bottom.

This take on prior contact, which still sparks its share of spooky cable TV offerings today, was launched in 1968 by von Däniken's *Chariots of the Gods?* The book became an international sensation and made believers of many agnostics. But the underlying premise of the book and all the other explorations it generated, says Michael Shermer, founder of the Skeptics Society, is built on a logical fallacy called *argumentum ad ignorantiam*, argument from ignorance. Shermer describes it like this: "If there is no satisfactory terrestrial explanation for, say, the Egyptian pyramids, then a theory that says they were built by aliens must be true."

For other people, aliens provide an explanation for otherwise baffling trauma. It too is an argument from ignorance, but this one is constructed at an acutely personal level. An otherwise rational everyman or -woman is awakened by flashing lights, rousted by hovering humanoid creatures, and teleported to a spaceship, where he or she is probed and prodded before being returned to terra firma. What else could make sense of an experience so vivid it results in measurable physiological responses comparable to those seen in post-traumatic stress disorder (PTSD)? Or explain why so many people have similar experiences? Extrapolation from polls conducted at the height of the late-20th-century UFO craze shows that hundreds of thousands, if not millions, of Americans experienced "symptoms" of alien abduction.

John Mack, a well-regarded Harvard researcher and author of a Pulitzer-winning psychological biography of T.E. Lawrence, was a co-organizer of that initial MIT conference who had become become intrigued by the numerous and detailed reports of contact. He set his sights on understanding why people wanted—or needed—to believe. At first, he was appropriately neutral about the reality of abductions. As he told the BBC, "I would never say, 'Yes, there are aliens taking people.' I would say, 'There is a compelling, powerful phenomenon here that I can't account for in any other way.'"

Over time, though, Mack began to sound more and more like one of his more enthusiastic subjects. One headline in the *Boston Herald* read e.t., phone harvard. The problem, he discovered, is that while whatever connection humans may have to aliens can be compelling, it is also fraught. Eventually, Harvard initiated a review

of Mack's methodology and, though he survived it and the surrounding swirl of media attention, any semblance of Mack as a disinterested scientist was dashed forever.

No matter; other academics were eager to fill the void. At the time, "recovered" memories were also much in the news; hypnosis and other psychological techniques were being used to enable individuals to "remember" sometimes-outlandish tales of sexual abuse and satanic rituals. Were these memories real? Particularly in the case of sexual abuse, it was often impossible to prove that the remembered abuse didn't occur. Harvard psychologist Richard McNally, who with colleagues had been studying post-traumatic stress disorder in war veterans and women who had been sexually abused as children, turned his attention to memories that featured an event very likely to not have transpired: abduction by aliens.

McNally found, somewhat surprisingly, that the experience of the abductees was perceived by them to be as real as the verified traumas of PTSD victims. But what feels real is not the same as what is real. In this case, McNally suspected the phenomenon known as sleep paralysis was to blame.

During REM sleep, we do not move; this is natural and useful because it prevents us from thrashing around, jumping out of bed or possibly injuring ourselves as we act out our dreams. Sometimes, though, we wake to find we are still immobile, and that can be extremely disorienting. According to Susan Clancy, one of McNally's former colleagues, when that happens, our brains try to help us cope with the odd feeling. "We can hallucinate sights, sounds and bodily sensations that seem real but are actually the product of our imagination," she explains.

Researchers have estimated that approximately 30% of us have undergone at least one episode of sleep paralysis, and about 5% of the time the episode was accompanied by a full range of visual, tactile and auditory hallucinations. Most episodes subside within a minute or so, but before they do, many sufferers are overcome with terror. How a person eventually reconciles the experience, says McNally, "depends on available cultural narratives." It isn't entirely clear why "some people opt for an alien abduction interpretation, while others assume they are haunted by a ghost"—or demons or witches or bogeymen camping under the bed, for that matter.

PROBING QUESTIONS John Mack, a Harvard professor and psychiatrist, took stories of alien abduction very seriously.

That aliens are among those apparitions lurking just below the surface of our consciousness should be no surprise, though. By the waning years of the 20th century, our cultural script had us primed to see aliens in every dark corner. “It is little wonder that abductees throughout the country report broadly similar kinds of alien encounters,” notes McNally. Nor is it a stretch, he explains, to see that “alien contact narratives have closely tracked the appearance of aliens and their spaceships as Hollywood has depicted them through the years.”

Spindly humanoid creatures—green or otherwise—with huge eyes and bulbous heads, they travel in rotating flying saucers decked out with floodlights. It’s a tried-and-true movie trope. And it is just such a description that supplies the casting for most abductees’ experiences. We tend to imagine what we can imagine, which is, give or take a detail here and there, what we have already seen.

BUT EVEN IF SLEEP PARALYSIS and late-night movies explain abductions to the satisfaction of most of us, they don’t begin to satisfy our need to calculate whether or not inquisitive aliens actually do exist somewhere, particularly now, when their cultural throw weight is only growing. For running alongside the near scientific certainty that neither you nor your normal-seeming neighbor has ever made contact with an alien is a scientific consensus that says the odds overwhelmingly favor the existence of intelligent extraterrestrial life somewhere in the universe. That we haven’t encountered it most assuredly does not mean it does not exist.

And having accepted the inevitability of extraterrestrials, we are then forced to ponder what sort of beings they might be. Many Earthlings assume that any aliens who would take the time and effort to roam the galaxy must have a malign agenda. After all, even if they are only as civilized as we are, that would clearly be alarming enough, right?

The political scientist Jodi Dean, who wrote the book *Aliens in America* in 1998, theorizes that this particular expression of alien life is our way of dealing with our own "anxieties over technological development and fears for the future." Others have suggested that the earlier alien invasion was a natural redirection of our Cold War fears. As the Soviet Union crumbled, aliens flew in to fill the breach, representing a different enemy, one perhaps even more implacable and merciless.

Still, there are others who think aliens don't have it in for us. Says Skeptics Society's Shermer, "The ET pessimists—those who think aliens are likely to be evil—are basing their assessment entirely on just one aspect of human nature. But over the past several centuries, our better angels have been slowly but surely overtaking our inner demons. The arc of the moral universe is bending toward justice." He adds that a successful space-faring civilization is just as likely to have learned to control its more aggressive tendencies and be willing to regard other sentient beings fairly. In short, Shermer says, "any ETs we encounter will be as morally advanced as they are technologically advanced."

That should offer a measure of comfort, even if the counterargument continues to nag. But what about Option C? What if our credulity runs smack into a brick wall? Because in the end, we might just be met with nothing. "Even if there is life throughout the universe, maybe intelligent life always screws it up," says Scharf with a rueful laugh. "Maybe it always gets to a point we're at now, where the need for resources runs away from it, and so it always messes up the environment and the civilization crashes. So maybe nobody anywhere really ever goes interstellar." Consider the impact, suggests Scharf, of finding out that there is some universal principle of intelligence: that those capable of becoming really smart get too smart for their own good. No news might not be good news.

No news also means we're left alone with our cosmic conjurings. Until further notice, they will continue to evoke cultural connections and individual reactions. And that is OK. To paraphrase the great French anthropologist Claude Lévi-Strauss, aliens are good to think with. Even if they don't always have us thinking straight.

BECAUSE IF IN THE LIGHT OF day, all this talk of aliens seems a little silly, well, that may just be the point. We humans are a rational species, but we are not a perfectly rational one. We often engage in a kind of magical thinking that allows us to believe the unbelievable, fathom the unfathomable. Each of our cultures has its own folklore, myths and legends, each of our religions its allegories, to help explain the world and give meaning to our existence. You might think that as our scientific knowledge expands, as more of the gaps in our understanding are filled, our reliance on magical thinking would diminish. Of course, that's not how it works. Just ask the billions of people for whom religion—or art or music or anything else that appeals to our less rational parts—still very much matters.

The fact is, mystery will always have its charms. Interestingly, McNally found that as terrifying as their alien experience may have been for the majority of abductees, they would not choose to have avoided it. "They said their encounters had deepened their spiritual awareness of the universe, making them glad there were powerful beings that cared for us and for the fate of the Earth," McNally says. "Some proudly mentioned their selection for hybrid breeding programs. Ninety percent said that, on balance, they were glad to have been abducted."

Why do we believe? Because the alternative is way too boring.

My Favorite Aliens

Maybe our fascination with extraterrestrials is a subtle record of our historic preoccupations. Or maybe we're just suckers for a good story. Either way, some of our pop culture starmen rise above the invading horde

BY JAMES PONIEWOZIK

A whirlwind was coming out of the north, a great cloud with raging fire engulfing itself . . . from within it came the likeness of four living creatures."

—THE BOOK OF EZEKIEL

THE BEINGS ENCOUNTERED BY the prophet Ezekiel may have been angels, but his vision can just as well be seen as literature's first reference to UFOs. Blinding brightness and flying wheels, the mood fearsome, mysterious and awesome—it has set the model for extraterrestrial visitation ever since.

Early alien stories were mostly scary ones; the Martian invasion of H.G. Wells's 1898 *War of the Worlds*, for one, was an early description of the deadly mechanized combat to come. Through the 20th century, though, the fictional cosmos grew more crowded, and our sci-fi relationships more complicated. The comics craze of

the ’30s and ’40s gave us iconic and upright interplanetary heroes, Krypton’s Superman and Earthling Flash Gordon. And post–World War II internationalism spawned aliens as enigmatic foreigners, as in Ray Bradbury’s *Martian Chronicles* and Robert Heinlein’s *Stranger in a Strange Land* . Still, it wasn’t long before growing Cold War anxieties had us circling back to alien-as-enemy, like the sleeper agents of *Invasion of the Body Snatchers* .

Once real-life astronauts began to make space a more accessible neighborhood, the aliens next door on our TVs turned goofier, from the quirky spaceman of *My Favorite Martian* to Fred Flintstone’s little green pal the Great Gazoo. The consciousness-raising ’60s and introspective ’70s contributed the enlightened aliens of *2001: A Space Odyssey* and *Close Encounters of the Third Kind* —righteous star-children who helped us find ourselves, man—not to mention the sweetly naive free-thinker Mork from Ork. Finally, the interstellar epics of George Lucas and Steven Spielberg reminded us of a simpler time, introducing us to a galaxy far, far away that offered old-fashioned high adventure (those starfighters were basically souped-up hot rods) and aliens who acted as childlike father figures, wanting little more in return than to eat our candy and phone home.

But, though we’ve confronted aliens as bald humanoids and giant insects, ravenous beasts and peaceful philosophers, in the end some of our most intriguing close encounters have had a strangely familiar feel. In 1968’s *Planet of the Apes*, for instance, Charlton Heston lands on a planet and is enslaved by primates; spoiler alert!—he’s on Earth after humans blew it up. And in 2014’s *Interstellar*, Matthew McConaughey got a mysterious assist from—spoiler alert again!—fifth-dimensional future humans. He has met the aliens, and they are us.

Point is, the make-believe universe is dense with characters of all types. Here are my favorite—and least favorite—Martians (Vulcans and Gungans too).

Alien rank is based on an aggregate of a vaguely scientific rating of five character traits. Rating system: 0 to 5 flying saucers.

1. Yoda

Power

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 21 saucers

Luke Skywalker's swamp sensei taught him—and us—that the Force was meant for more than slicing and dicing with light sabers. The wee wizened one spoke of self-control ("Do or do not; there is no 'try' ") and the danger of hatred. Of course, in the *Star Wars* prequels, he was happy to back up his elevated lessons with some Sith-kicking action. The greatest of all time, he is.

2. Spock

Power
Intelligence
Friendliness
Weirdness
Humor

OVERALL: 18.5 saucers

So he has no emotions; the Enterprise's half-Vulcan science officer has personality to spare. Rational and cool yet loyal and dedicated, he is a foil for humankind's hotheadedness. But he can also melt hearts—his farewell to Captain Kirk in *Star Trek 2: The Wrath of Khan* is a poignant capper to sci-fi's No. 1 bromance.

3. Mork

Power

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 18 saucers

Hatched from a space egg—but really from the fertile, frenetic brain of the late Robin Williams—the compact Orkan stands at the head of a lengthy line of sitcom aliens. His mix of stream-of-consciousness comedy and childlike wonder charms us, and his confusion at our Earthling ways cracks us up while making it quite clear that, more often than not, we're the weird ones.

4. E.T.

Power	
Intelligence	
Friendliness	
Weirdness	
Humor	

OVERALL: 17.5 saucers

How many movie characters, human or otherwise, have ever said so much with such a limited vocabulary? Spielberg's lost traveler warms our heartlights with a sentimental longing for home even as he indulges our kid's sense of adventure (who wouldn't be happy to take that airborne bike ride?). He tells us that decency is universal, and we eat it up like so many Reese's Pieces.

5. The Doctor

Power
Intelligence
Friendliness
Weirdness
Humor

OVERALL: 17 saucers

The screwdriver-wielding Time Lord of Britain's *Doctor Who* is long-lived in more ways than one: his theoretical immortality doesn't begin to explain how he's managed to regenerate into 12 incarnations or stay on the air for more than half a century. Credit the fact that he always gives the people what we want. He's the ultimate in brain over brawn, a pacifist who solves problems with ingenuity, a little help from his human pals and a time-traveling phone kiosk. The decades change and so do the faces, but the Doctor is always in.

6. Marvin the Robot

Power
Intelligence
Friendliness
Weirdness
Humor

OVERALL: 16.5 saucers

The *Hitchhiker's Guide to the Galaxy* books feature all manner of odd creatures: cows that beg to be eaten, aliens who kill with bad poetry. But Douglas Adams's finest creation is this chronically depressed robot—or "paranoid android," in the words of his companion Zaphod Beeblebrox—who faces life, the universe and everything with a morose sarcasm that is sneakily profound: "Life. Loathe it or ignore it; you can't like it."

7. Groot

Power

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 15.5 saucers

"I. Am. Groot." No, this burly, barky beast out of *Guardians of the Galaxy* isn't long on conversational skills (or blood cells). Still, the interstellar tree-man is mighty as an oak, and turns out to possess a brave and generous—if wooden—manner as well. Yes, he is Groot. And. He. Is. Awesome.

8. The Borg

Power
Intelligence
Friendliness Zero
Weirdness
Humor Zero

OVERALL: 15 saucers

Star Trek's Borg is (are?) as much a concept as a race: a collective intelligence that assimilates other peoples' thoughts to create an ever-growing hive mind fixated on continuous expansion. This invention has redefined our idea of a species; something more like a virus, it (they?) infects galaxies in pursuit of "perfection." And if the Borg never quite achieves that, as far as villainous watchability goes, resistance is futile.

9. Kang & Kodos

Power

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 14.5 saucers

The perpetual droolers featured each year in *The Simpsons*'s "Treehouse of Horror" episode are a full-service source of sci-fi parody, running the gamut from terrifying to buffoonish. Maybe their greatest turn came during the 1996 presidential election, when they took the form of the two candidates Bill Clinton and Bob Dole: "It makes no difference which one of us you vote for—either way, your planet is doomed!" It's funny because it's true.

10. The Prawns

Power Zero

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 14 saucers

We've witnessed aliens as conquerors and aliens as all-powerful friends. But the social allegory that is Neill Blomkamp's *District 9* imagines them as refugees—oppressed interstellar misfits corralled into apartheid-esque reservations by suspicious and bigoted Earthlings. Never have creatures so crustacean seemed so human.

11. The Iron Giant

Power

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 13.5 saucers

Brad Bird's animated movie (from a Ted Hughes novel) tweaks the *E.T.* arc—boy meets alien, boy brings alien home—into a parable of Cold War paranoia. Sure, the overgrown tin man is cold and hard on the outside. Inside, though, he's warm and fuzzy.

12. The Apes

Power
Intelligence
Friendliness
Weirdness
Humor

OVERALL: 13 saucers

OK, so technically, *The Planet of the Apes*'s simians aren't extraterrestrials at all. To be fair, though, we don't find that out until the end of the original movie. Besides, these talking primates sure seem alien. Their treatment of surviving humans as a subjugated underclass, of course, makes it clear that they're not necessarily the good kind.

13. Superman

Power
Intelligence
Friendliness
Weirdness Zero
Humor Zero

OVERALL: 12.5 saucers

He was from another planet long before he took a day job at the *Daily Planet* . But it is the powers gained under our yellow sun that allow him to moonlight as the archetypal modern superhero. If we're being honest, though, that truth-justice-and-American-way earnestness plus a near invincibility also makes him a bit boring. Still, Lois Lane is onto something; there's no one you'd rather have on your side in a jam.

14. The Alien

Power

Intelligence

Friendliness Zero

Weirdness

Humor Zero

OVERALL: 12 saucers

As dramatic entrances go, it's hard to beat one in which the critter in question bursts out of an unfortunate astronaut's chest before skittering away. But while Ridley Scott's *Alien* is undeniably a sci-fi-horror classic unmatched in its claustrophobic terror, the titular villain is really more prop than character. Think about it—isn't something more chilling when you don't see it than when you do?

15. Alf

Power
Intelligence
Friendliness
Weirdness
Humor

OVERALL: 11.5 saucers

If Mork and Mindy gave us the alien as hyperactive gonzo comic, this later sci-fi sitcom presents the alien as Borscht Belt entertainer. Furry alien ALF (a.k.a. Gordon Shumway), from the lost planet Melmac, is an uninvited guest in a suburban home, his taste for one-liners rivaled only by one for cats. ALF is the snarky alter ego to the sentimental E.T. character, but his appeal is never more than cornball, if not downright furball.

16. *Close Encounters* Visitors

Power 🛸🛸🛸

Intelligence 🛸🛸🛸🛸

Friendliness 🛸🛸🛸

Weirdness 🛸

Humor Zero

OVERALL: 11 saucers

Don't get me wrong—the movie is spectacular, offering a most compelling case for first contact as a moment of wonder, not fear. But as ETs go, these are enigmatic; for most of the movie, we know them only by their spacecraft and catchy five-note siren call. When they finally do show up, it is as silent, generically bulb-headed spacemen. Great musical ear. Meh personality.

17. *War of the Worlds Martians*

Power
Intelligence
Friendliness Zero
Weirdness
Humor Zero

OVERALL: 10.5 saucers

There is no doubt that H.G. Wells's aliens—a sort of otherworldly calamari that emerge from cylinders—are the advance guard for generations of fictional invaders to come (including the Orson Welles radio drama of the same story that caused a national panic in 1938). But taken out of historical context, they are generic slime monsters whose end comes ignominiously as they succumb to common Earth germs. If you want to be a top-tier space villain, you've gotta be able to survive a cold.

18. Marvin the Martian

Power
Intelligence
Friendliness Zero
Weirdness
Humor

OVERALL: 9 saucers

Sure, Bugs Bunny's pint-size enemy with planet-size ambitions of intergalactic conquest has his charms. But I can still remember how disappointed I was—or in his words, "very angry indeed"— whenever one of Marvin's Looney Tunes shorts came on. I'm sorry, but given the choice, I'd rather watch a Yosemite Sam or Elmer Fudd cartoon any day.

19. The Great Gazoo

Power Zero

Intelligence

Friendliness

Weirdness

Humor

OVERALL: 8.5 saucers

Long before sitcoms began to jump the shark, *The Flintstones* jumped the saucer with this wisecracking sidekick (a little green blot on the résumé of the great comic actor Harvey Korman, who performed his voice). Gazoo is now a symbol for desperation moves of shows past their creative peak; *The Flintstones* was canceled after the season in which he appeared, making him, in some ways, one of TV's most deadly aliens.

20. Jar Jar Binks

Power	Zero
Intelligence	Zero
Friendliness	
Weirdness	
Humor	Zero

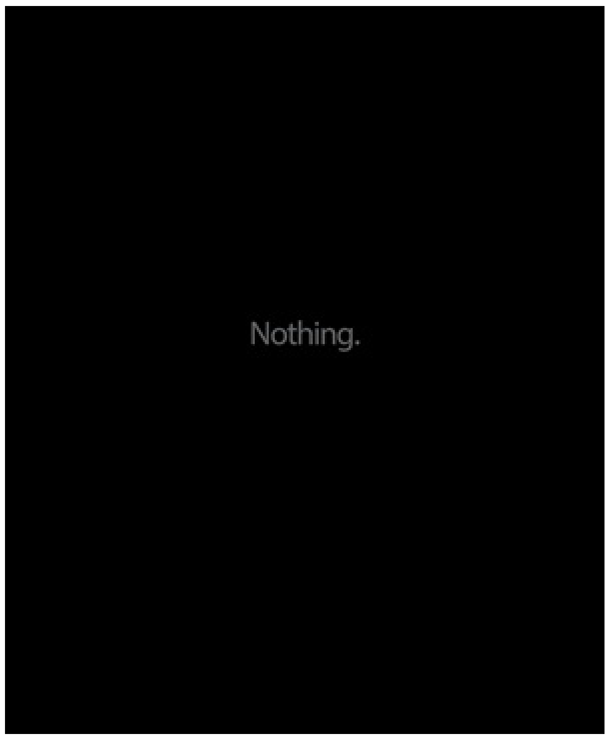
OVERALL: 7 saucers

He is the anti-Yoda, a pratfalling abomination from the first *Star Wars* prequel who almost did more damage to that universe than the Emperor himself. Goggle-eyed and goofy—with an offensive, quasi-Caribbean accent to boot—he seems as if he walked off the set of a daytime TV show for preschoolers. His floppy-eared head bears the enduring anger of fans who think the prequels siphoned off the colossal franchise's magic. So maybe the problem is that he was miscast. After all, every space opera needs its villain.

Maybe We Are the Only Ones

Even scarier than thoughts of impending alien invasion is the existential possibility that we are all there is in the universe. It may seem a long shot, but some smart people would not be at all surprised if it were true

BY JEFFREY KLUGER



YOU MAY AS WELL START TO buddy up with life on Earth—every microbe and mammal, every bird and bug, every tree and plant and fungus and fish. Most of all, you'd better buddy up with us, human beings, the species that sits atop this whole pyramid of living things. Because when it comes to biology, our planet may be the whole show.

Forget the overwhelming math, specifically, those trillions upon trillions of planets. Snuff out the one match head that is life on Earth, and the whole vast universe goes biologically black. We can search for extraterrestrial life all we want, send up all the here-we-are signal flares we can invent, but the fact is, no one will answer—ever—because no one is there.

That, like it or not, may be the dispiriting truth, and it's not just naysayers and picnic skunks who say so. Some very credible researchers have crunched the

numbers and run the odds and taken a good hard gander at them without the little frisson of hope even many of the most serious scientists bring to their work. And if that tingle of optimism may bias their work, the believers can be forgiven their illusions. For a long time, credible science has made a strong case for alien life. So it's hard to accept the backpedaling now.

Perhaps the most influential of the life-is-out-there advocates, astronomer and SETI Institute founder Frank Drake, made his bones in the extraterrestrial game with his eponymous equation, a satisfying—if coldly arithmetical—case for the likelihood not only of life in space but of intelligent life. According to Drake, the *n* in his equation—the number of civilizations in the Milky Way alone capable of producing detectable radio signals—equals the rate of the formation of sunlike stars in our galaxy, times the proportion of stars that are orbited by planets, times the proportion of those planets that would offer life-supporting conditions, times the fraction representing planets on which life does exist, times the fraction representing life-forms that are intelligent, times the fraction representing intelligent life-forms that can transmit signals, times the length of time such a civilization actually sends those signals before either perishing or going dark for any other reason.

Simple, right? Honestly, it kind of is. Filling in all of the *x* 's in the equation—which, admittedly, is itself an act of conjecture, albeit highly informed conjecture—typically yields an estimate of thousands of civilizations. Drake himself put it at 10,000. The late cosmological popularizer Carl Sagan estimated the figure at an astounding 1 million. Even if they were off by a factor of 10 or 100 or even 1,000, it is fairly obvious that we are not remotely alone.

Unless we are.

Paul Davies, a cosmologist at Arizona State University and the author of the book *Eerie Silence* —which takes exactly the dim view of our ever encountering an alien intelligence that its title suggests—is a sort of philosophical counterpoint to the point that is Drake. There is almost no part of the intelligent-life argument that he finds persuasive.

THE BIGGEST HOLE HE FINDS in the Drake equation is the one involving the subset of planets that could support life that actually do. The fact is, we have absolutely no empirical data of any kind that allows us to put a value to that variable in a responsible way. We know of precisely one world on which life has existed, and the rest is largely guesswork. Fill in that one Drake blank with a zero,

and the entire equation collapses to zero too.

Davies, though, goes well beyond the flaws of the equation, arguing that there is a perfectly credible case to be made for the presence of life on Earth as a result of a succession of flukes, each more improbable than the one before it, which, together, could occur only a single time in a trillion trillion tries. A chimp randomly pounding a typewriter might indeed come up with *Hamlet* . Once. It wouldn't matter if there were 40 billion other chimps hammering away, just as, as Davies has written, it doesn't matter if there are 40 billion planets in the Milky Way capable of sustaining life. Only a single one will.

Furthermore, he believes that in the improbable event an intelligent civilization exists, it is surpassingly unlikely it would send any messages our way. The popular notion is that because we've been transmitting radio and TV signals for more than a century now—and because those signals are spreading into space at the speed of light—surely a sophisticated species would have gotten wind of us by now. Problem is, in a universe that stretches for 13.8 billion light-years in all directions, the 100 light-years our signals have traveled so far make them a decidedly local broadcast.

Most discouraging is that in all the years we've been looking for an extraterrestrial sign (and no, crop circles don't count), there has been, well, only an eerie silence. SETI's antennas have been pointed skyward for half a century, listening for a repeating signal that would suggest an intelligent sender; so far, nothing. There was that one thrilling moment—on Aug. 15, 1977—when SETI scientist Jerry Ehman, working with Ohio State University's radio telescope, picked up a signal a full 30 times as strong as the background noise of deep space. It was tracked for 72 seconds and had a frequency similar to that of the spectral line for hydrogen. (That's relevant because SETI scientists have long believed that since hydrogen is the most common element in the universe, it might be chosen as a sort of universal sending frequency.)

On the printout that the radio telescope produced of the signal, Ehman wrote one word: "Wow!" Forevermore, what he heard that night has been known as the Wow! signal. It was never heard again, though, and today the signal is assumed to have been an atmospheric anomaly, a reflection from space debris or of earthly origin. What it almost certainly was not was an alien semaphore.

Of course, it's much too early to consider any of this proof of a negative. The universe is huge and ancient, and a 50-year exploration isn't even a single pixel in

the sweeping mural of time. Science does make hard, sudden turns: one day there was no Copernicus saying the Earth isn't the center of the universe, and then there was—and nothing was ever the same again. Ditto Einstein and his relativistic universe; ditto Leeuwenhoek and the previously unseen biosphere revealed by his microscope. And so it could still well be with the discovery of alien life.

Until then, there may be something to be gained from thinking of the Earth as the universe's only wilderness preserve. If life is indeed a cosmic one-off, it makes it all the more important that we be this planet's responsible caretakers. Snuff this biological light, and the descending darkness won't just be our fault. It will be our crime.

Credits

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